Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario

Ontario

ASBESTOS IN BUILDINGS

A Study Prepared By:

Donald J. Pinchin

Study Series

Study No. 8

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Donald J. Pinchin

for

The Royal Commission on Matters of Health and Safety

Arising from the Use of Asbestos in Ontario

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This study was commissioned by the Royal Commission on Asbestos, but the views expressed herein are those of the author and do not necessarily reflect the views of the members of the Commission or its staff.

June 1982

A S B E S T O S   I N   B U I L D I N G S

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PREFACE

This study was initiated while the author was employed at the Ontario Research Foundation. The contributions of Ontario Research Foundation staff to the overall study are therefore considerable. The air monitoring was performed by Bruce Stewart and Shanna Bennett of the Department of Environmental Chemistry. The transmission electron microscopy was performed by Eric Chatfield, Jane Dillon and the staff of the Electron Optical Laboratory in the Department of Applied Physics. Optical microscopy was performed by Jackie Terry and the building inspections were performed in part by Ray Hemmings of the Department of Materials Chemistry. The author wishes to thank all those involved for their co-operation and careful work.

The author also wishes to thank many contractors, consultants, building owners, and government and school board officials who contributed their time and information so freely. Many of these people are referenced in the text of Chapters 2, 4, 5 and 7, however, not all wished to be so acknowledged. Without their help, this study would have been impossible.

Finally, I wish to acknowledge the planning and administrative assistance of Cyril Gibbons of Ontario Research and the staff of the Royal Commission on Asbestos who showed such patience. The secretarial work of Colleen Gordon, Pat Mines, Cathy Harding and Gayle Johnson is also greatly appreciated.

Any remaining errors or omissions remain the sole responsibility of the author.

June 1982

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CHAPTER 1

POTENTIAL ASBESTOS CONTAMINATION AND CORRECTIVE MEASURES; EXPERIENCE FROM OTHER JURISDICTIONS

1. INTRODUCTION

The health hazards of airborne asbestos fibres to workers in the asbestos industry have been known for a number of years. Only recently has the possibility of widespread asbestos-related disease from non-occupational exposure been considered. The medical aspects of this low level or intermittent non-occupational exposure to asbestos have been reviewed in public meetings held in the summer of 1981 (1) by the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario (hereafter called the Royal Commission on Asbestos). These medical aspects will not be considered in this study which concentrates only on the potential or actual fibre levels detected in buildings due to asbestos use in the building.

It is known that asbestos can be detected at low background levels in the environment both in air (2) and in water (3). Therefore the presence of airborne asbestos fibres in a building cannot be used as definitive proof that an asbestos-containing building product is indeed releasing significant amounts of asbestos fibre to the building environment. The present research study, instituted by the Royal Commission on Asbestos, will provide a data base of fibre levels in buildings in an effort to establish a criterion for deciding whether a particular installation does require remedial work. In addition the study will provide information on the cost and effectiveness of various procedures in reducing exposure to asbestos, information on current control programmes in Ontario,and an estimate of the extent of the problem in Ontario.

This chapter is largely based on information collected from other jurisdications, namely Britain, France, the United States of America, and Australia. It will cover: asbestos-containing products used in buildings; the relative hazard of various products or installations; available methods for asbestos abatement; methods of management and control of asbestos where appropriate; and methods of selecting and performing any necessary contractual work.

2. ASBESTOS-CONTAINING PRODUCTS USED IN BUILDING

A very wide range of products used both in the construction industry and elsewhere contain asbestos. Although the list of these products is shrinking as replacement materials are found, a number of asbestos uses currently have no acceptable replacement. Table I presents a summary of selected asbestos products and their end uses. Although between 2000 and 3000 uses of asbestos have been identified, the uses shown in Table I will account for a very high percentage of the total asbestos consumed.

The asbestos-containing products used in construction can be generally divided into two classes, depending on the hardness and possibility of fibre release. Hard products which contain asbestos fibre bound in a solid matrix are not generally considered to pose any significant risk of releasing airborne fibres during normal use(4, 10). This category includes such products as floor tile, gasket material, roof coating and patching compounds, asbestos cement products, hard ceiling tiles and impregnated textile and paper products. Only during sanding, grinding, cutting or other processes used in installation or alteration of these products might fibre release be significant. Airborne fibre levels detected during various operations on these materials have been extensively reported (5, 6). These publications and many others contain specific guidelines to reduce exposure to airborne fibres during these specific activities.

A clear distinction can be made between these products and friable asbestos material which is defined typically as follows: "'Friable asbestos material' means any material that contains more than 1 percent asbestos by weight and that can be crumbled, pulverized, or reduced to powder, when dry, by hand pressure." (7) Only products which fall into this category of "friable asbestos material", or processes involved in mining, milling or manufacturing asbestos-containing products are included in most asbestos control regulations.

Sprayed asbestos-containing insulating material and low density pre-formed asbestos-containing insulating blocks do, however, fall into this category of friable asbestos material and have been widely used in buildings.

TABLE I

SELECTED ASBESTOS PRODUCTS AND THEIR END USES

FLOOR TILE	GASKETS AND PACKINGS	FRICTION PRODUCTS	PAINTS, COATINGS AND SEALANTS	ASBESTOS-REINFORCED PLASTICS	ASBESTOS CEMENT PIPE
Office floors	Valve components	Clutch/transmission components	Automotive/Truck body coatings	Electric Motor components	Chemical process piping
Commercial floors	Flange components	Brake components	Roof coatings and patching compounds	Molded product compounds for high-strength/ weight uses	Water supply piping
Residence floors	Pump components	Industrial friction materials			Conduits for electric wires

ASBESTOS TEXTILES	ASBESTOS PAPER	ASBESTOS CEMENT SHEET
Packing components	Gas vapor ducts for corrosive compounds	Hoods, vents for corrosive chemicals
Gasket components	Fireproof absorbent papers	Chemical tanks and vessel manufacturing
Roofing materials	Table pads and heat protective mats	Portable construction buildings
Commercial/industrial dryer felts	Heat/fire protection components	Electrical switchboards and components
Heat/fire protective clothing	Molten glass handling equipment	Residential building materials
Clutch/transmission components	Insulation products	Molten metal handling equipment
Electrical wire and pipe insulation	Gasket components	Industrial building materials
Theater curtains and fireproof draperies	Underlayment for sheet flooring	Fire protection
	Electric wire insulation	Insulation products
	Filters for beverages	Small appliance components
	Appliance insulation	Electric motor components
	Roofing materials	Laboratory furniture
		Cooling tower components

Source: Asbestos Information Association/North America

Information is now available that these products can release fibres into the building environment during normal use or routine maintenance (8, 9, 10, 11). It is these products which are considered to be potentially capable of releasing fibres to the building environment during their life cycle and which will be addressed by this study. Elevated fibre levels incurred in the construction industry during installation of these (12) or other products (13) will not be considered as these products have been largely removed from the market or described in other publications (5, 6).

2.1 Friable Materials in Buildings

The useful properties of asbestos include high strength incombustibility, good insulating properties, and the ability to produce fine fibres which can be woven into fabrics. These properties are utilized in the products which are usually considered to pose the greatest risk of fibre release during use -- friable sprayed insulating products, pre-formed thermal insulating blocks, and uncoated textile products. The sprayed insulating products and pre-formed thermal insulating blocks are most widely used in buildings.

The sprayed insulation materials are the most likely to cause asbestos exposure to construction workers during application or in posing a danger of fibre release thereafter. Spray application of asbestos-containing insulation material has been reported to date from 1932 in Great Britain, where it was used for condensation control and acoustical purposes (24). It was introduced into the United States in 1935 and shortly afterward into Canada. Most of the early North American uses were for decorative sprayed coatings and acoustical control. It was soon found useful as a fireproofing coating and was given Underwriters Laboratory approval as such in 1950. There was extensive use of this product for the fireproofing of structural steel. The combination of fireproofing and acoustical properties accounts for its widespread use in schools and public areas of buildings such as airports. The spray-on products were applied in North America until the early 1970's when replaced by other non-asbestos products.

The potential hazard of the sprayed products depends largely on the asbestos content, strength, binder content and hardness of the material. These in turn depend largely on the method of application and skill of the contractor. The two main methods of application are the wet and dry processes.

In the wet method, asbestos (generally 5% to 30% by weight of the total formulation) and some combination of other fibres (mineral wool, glass, cellulose) and lightweight aggregate (perlite, vermiculite) were mixed with the binder (portland cement, gypsum) and water to form a slurry in a ribbon blender. This slurry was then pumped and applied with an air spray to the required location. The product when cured tended to be quite hard and relatively dense (greater than 20 pounds per cubic foot). When applied as a fireproofing coating, the maximum thickness of the slurry applied product was usually one inch with most applications being closer to one-half inch. When applied for decorative use or acoustical purposes, the thickness of application was usually very much lower. As a general rule, these formulations contained chrysotile asbestos or a chrysotile/amosite asbestos mixture.

The dry method used a dry blend of asbestos fibres (anywhere from 5% to 90% by weight) with some combination of mineral wool, fibrous glass, portland cement, gypsum or water soluble resins. These dry materials were blended and blown through the delivery pipes with an air stream. As the dry material left the nozzle, it passed through a ring of water jets. This wetted the dry material thoroughly, activated the binders, and stuck the product to the application surface. The material had a much lower density as applied (less than 15 pounds per cubic foot) and was usually applied in thicknesses from one to two-and-one-half inches thick. Often an adhesive was applied to the surface of the fibrous mat. The material was also often rolled or tamped into place although with the lower density the product remained softer than the wet-applied product. The formulations usually contained one of two types of asbestos: amosite (usually more than 50% by weight) or chrysotile (5% to 50% by weight). Crocidolite asbestos was less commonly used in North America but is found in a small number of the dry-applied installations. The asbestos content is often found to vary significantly from one location to another within a single building because of the method of mixing and application.

The pre-formed thermal insulating blocks found extensive use for lagging pipes, boilers, furnaces, etc. from the mid 1920's until the early 1970's. As in the case of the sprayed materials, many different binders and fibre contents are found in these products although magnesium-carbonate or calcium-silicate bonded blocks predominate. Both amosite and chrysotile were used in these products, depending on the manufacturer and the application for which the product was intended. Most of these products when applied are held in place with wire or wire mesh and are coated with a jacket of painted paper, canvas or cotton.

A number of other products containing asbestos were also used for specialized lagging purposes on piping or electrical conduit. These specialized products include rope lagging (specifically for use on elbows or awkward shapes), corrugated asbestos paper (used for moderate temperature piping), or cable listing (a ribbon-like asbestos textile used for insulating electrical cables). Asbestos paper was also used in some electrical insulation applications. Asbestos fibre was also incorporated in products mixed with water and applied on elbows, valves, boilers, or irregular shapes. These products were called asbestos cement, asbestos insulating cement, finishing cement, or cold water paste. Like the pre-formed blocks, many of the installations of these products were coated with a layer or layers of paper or cloth and were often painted. In this form it is difficult to identify immediately its presence in a building unless the covering has become damaged. The pipe and boiler insulation tends to become very dusty after it has been exposed to elevated temperatures in use.

The installation of sprayed material (12) and pre-formed insulating blocks (8) as well as some non-friable asbestos-containing building products such as patching and taping compounds (13), have been shown to expose the worker to very elevated levels of asbestos fibres. Only the sprayed material and the pre-formed insulation block or lagging products used for boiler, furnace or pipe insulation have been shown to produce elevated levels either in place or during demolition.

3. ASBESTOS-CONTAMINATION IN BUILDINGS

As stated in a recent report on asbestos, "Asbestos is only harmful if fibres are released and inhaled, and thus measurements of dust concentrations or some estimate of them is necessary to assess the exposure of the individuals to asbestos and thus any possible risk to them." (14) Several reports have been issued which attempt to quantify the level of airborne asbestos in buildings. These will be reviewed in this section. Data from a number of Ontario buildings is presented in a later chapter of this study.

3.1 Modes of Contamination

The general modes of contamination of building air by asbestos fibres from friable insulating material have been identified by Sawyer (9) and slightly modified by Lory *et al.* (15). These modes of contamination are:

(a) Fallout or erosion produces a continuous low level of fibre release. It is caused by degradation of the insulation material or by air flow over the material, as in an air plenum.

(b) Impact produces a high release rate of fibres when the surface is subjected to mechanical impact. This impact may be due to routine activity, maintenance or vandalism.

(c) Secondary dispersal or re-entrainment is produced by the disturbance of asbestos fibres which have already fallen onto interior surfaces. The amount of contamination produced by this mechanism depends on the amount of material which has settled. This secondary dispersal may be due to normal activity or building cleaning.

(c) These mechanisms are shown diagrammatically in Figure 1. The influence of the various modes of contamination have been reported in several publications (9, 11, 15) and are summarized in Table II.

FIGURE 1

MODES OF CONTAMINATION

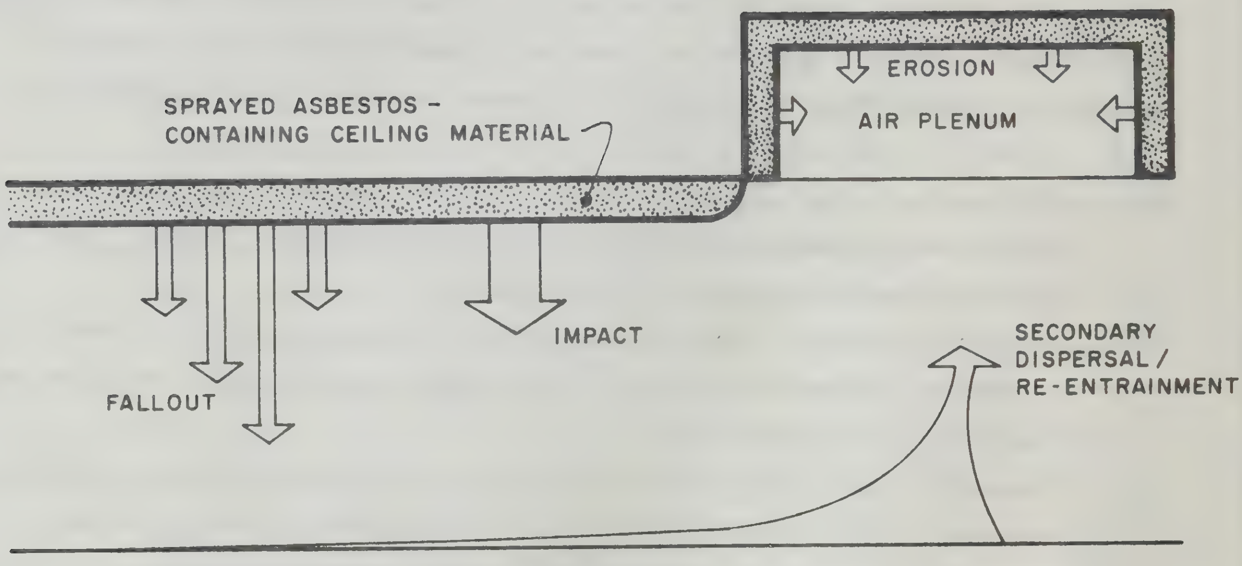

TABLE II

MODES OF CONTAMINATION

MODE	CAUSES	FREQUENCY	FIBRE RELEASE RATE
FALLOUT/ EROSION	AIR MOVEMENT, VIBRATION, DETERIORATION	CONSTANT	LOW
IMPACT	MAINTENANCE, ACCIDENTAL IMPACT	OCCASIONAL	HIGH
SECONDARY DISPERSAL/ RE-ENTRAINMENT	USUAL ACTIVITY, CUSTODIAL SERVICE	FREQUENT	LOW TO HIGH

Sebastien (11) concluded after extensive air monitoring that the levels due to fallout or erosion alone were always very much lower than when activities producing secondary dispersal or re-entrainment were operating. This observation clearly indicates that air samples taken under conditions of still air are not an accurate measure of the level of occupant exposure in normal use. This has been confirmed by Sawyer (9).

Although impact certainly results in the highest short-term release rate, it is extremely difficult to measure the airborne fibre levels produced by this occasional phenomenon. Sebastien concluded that the mechanism of pollution inside a sprayed building occurs as follows: sedimentation of "large" particles by fallout, erosion, or impact followed by fragmentation and secondary dispersal. Therefore, Sebastien concluded that secondary dispersal seems to be the sufficient condition to establish measurable pollution - the necessary conditions being provided by fallout, erosion, or impact.

3.2 Typical Levels Detected

In an effort to determine whether the presence of a friable asbestos material in a building actually results in elevated airborne fibre levels, air monitoring has been widely used (9, 10, 11, 15, 18, 19, 24, 27, 39). The results have been quite variable within a single building, within the results of a single study and between different studies. Often the results are not comparable between different studies since different methods of monitoring or fibre counting have been used. There also appears to be some systematic variability between airborne levels measured in different geographical locations. This may be due to the experimental method or may in fact be a genuine phenomenon.

Results obtained in the studies reported here have generally been analysed by either the optical microscope using the phase contrast method or by transmission electron microscopy (TEM). Although several authors have attempted to relate results obtained by these methods, there is generally poor correlation between the methods (16, 17, 24, 28). The results obtained by each of the methods will be considered separately.

3.2.1 Optical Microscopy

The results obtained by various authors (9, 18, 19, 39) using optical microscopy are summarized in Table III. It should be stressed that optical methods do not identify the fibres observed in the microscope. Any particle with a length greater than 5 micrometres and a length to diameter ratio of 3 to 1 or greater is included in the count. This will result in non-asbestos fibres being included in the air sampling results. The very fine fibres of asbestos (usually less than 0.3 micrometres) are below the effective resolution of the optical microscope and these fine fibres will not be observed by optical microscopy. While it is generally accepted that 0.1 fibres per millilitre of air (f.mL-1) represents the lower limit of reliable quantitation for analysis by phase contrast microscopy (29, 30), many authors report fibre concentrations of less than 0.1 f.mL-1 . Their results will be used as originally reported.

TABLE III

Airborne Asbestos in Buildings Analysed by Optical Microscopy

Conditions of Sample Collection	Mean Counts fibre.mL-1	Number of Samples	Standard Deviation fibre.mL^{-1}
Sprayed crocidolite, behind suspended ceiling, (18) no air plenum	0.05	4	0.03
Sprayed amosite/fibreglass, behind suspended (18) ceiling, no air plenum	0.03	5	0.01
Sprayed amosite/fibreglass/chrysotile, (18) behind suspended ceiling, no air plenum	0.04	4	0.01
Sprayed crocidolite, behind suspended ceiling, (18) no air plenum	0.04	5	0.04
Sprayed amosite/chrysotile, behind suspended (18) ceiling, used as air plenum	0.04	4	0.01
Sprayed crocidolite/amosite, behind suspended (18) ceiling, no air plenum	0.05	6	0.01
Sprayed amosite, exposed through holes in tile (18)	0.18	4	0.05
Sprayed chrysotile, in auditorium (18)	0.10	3	0.02
Sprayed amosite, exposed on roof deck (18)	0.06	6	0.01
Sprayed crocidolite/amosite, behind suspended (18) ceiling, no air plenum	0.01	4	0.005
Sprayed amosite, behind suspended ceiling, (18) no air plenum	0.04	3	0.01
No asbestos (average of three buildings) (18)	0.03	15	0.01
Worker checking ventilation in ceiling space (18) with sprayed asbestos	1.3	4	1.1
Worker altering ceiling fittings in ceiling (18) space with sprayed asbestos	1.5	4	0.6
Worker removing ceiling tiles in ceiling (18) space with sprayed asbestos	5.45	2	0.07
Worker wiring and moving cables in ceiling (18) space with sprayed asbestos	0.93	4	0.78

TABLE III (continued)

Conditions of Sample Collection	Mean Counts $fiber.mL^{-1}$	Number of Samples	Standard Deviation $fibre.mL^{-1}$
Library, exposed 20% chrysotile, quiet conditions (9)	0.02	15	0.02
Library, exposed 20% chrysotile, cleaning books (9)	15.5	3	6.7
Library, exposed 20% chrysotile, re-lamping light fixtures (9)	1.4	2	0.1
Library, exposed 20% chrysotile, removing ceiling section (9)	17.7	3	8.2
Library, exposed 20% chrysotile, installing track lights (9)	7.7	6	2.9
Library, exposed 20% chrysotile, installing hanging lights (9)	1.1	5	0.8
Library, exposed 20% chrysotile, installing partition (9)	3.1	4	1.1
Library, exposed 20% chrysotile, dry sweeping (9)	1.6	5	0.7
Library, exposed 20% chrysotile, dry dusting (9)	4.0	6	1.3
Library, exposed 20% chrysotile, normal inhabitant activity (9)	0.2	36	0.1
Office, exposed 5 to 30% chrysotile, vigorous dusting (19)	2.8	8	1.6
Private home, removing amosite and chrysotile pipe lagging (19)	4.1	8	1.8-5.8*
Dormitory, exposed 98% amosite, general activity (19)	0.1	-	0.0-0.8*
Warehouse, badly deteriorated, falling and exposed crocidolite, low activity (39)	0.26	8	0.1-1.26*
Warehouse, badly deteriorated, falling and exposed crocidolite, high activity (39)	2.76	8	0.03-10.31*
Warehouse, badly deteriorated, falling and exposed crocidolite being disturbed (39)	11.89	16	0.3-52.6*

*Range ($fibre.mL^{-1}$)

Considering the data from the South Australian Health Commission (18) it is clear that the levels of airborne fibre in buildings sprayed with asbestos-containing material are very similar to the fibre levels detected in buildings without asbestos, under normal conditions. The average background fibre level in buildings without sprayed asbestos fibre was 0.03 f.mL-1 with the maximum value 0.05 f.mL-1. Only two buildings-- one which contained sprayed amosite which was exposed through holes in the ceiling tile, and one with chrysotile in an auditorium --showed significantly elevated fibre levels. Therefore, on the basis of these results, one of two conclusions can be drawn: either only the two buildings show any need of remedial action, or the optical method of air monitoring is inappropriate to determine the potential hazard in a building. In fact, the authors suggested that both of these conclusions may be valid.

The more significant data from this source, particularly by comparison to the samples taken under normal conditions, are the personal samples taken on maintenance employees. These results obtained from workers engaged in maintenance above the suspended ceiling are very significantly elevated, ranging from 0.93 to 5.45 f.mL-1. These samples were all obtained as personal samples taken for the duration of the work. In none of the cases monitored was the sprayed coat directly disturbed. The report concluded that "maintenance and alteration work in buildings containing sprayed asbestos carried a much greater potential risk than does simple occupancy of the building" and that "precautionary procedures were clearly indicated in such operations."

Data reported by Sawyer (9) from the Yale library appears to generally confirm the above conclusions regarding the fibre levels in general occupancy relative to maintenance and alteration work. Sawyer's data was obtained in a building sprayed with a mixture of asbestos (15% chrysotile by weight), fibrous glass, and cementitious binder in a fully exposed condition. Sawyer describes the material condition as follows:

"The exposed and friable ceilings soon began gradual deterioration as air currents, ventilation leaks, and vibration resulted in fiber loss. In addition, many of the ceilings, only 80 in. (203 cm) high in some areas, were

easily reached and were subject to both accidental and capricious contact." Sawyer also describes "the dislodgment of a full thickness of ceiling by students. Electrical and plumbing services were enclosed above the suspended ceilings, and coated Sheetrock formed the floor of the forced-air plenums that ran the length of most rooms. Maintenance work and installation of fixtures or partitions involved contact with the ceiling, and fibre release." In spite of these conditions, samples taken in quiet conditions yielded fibre levels of only 0.02 f.mL-1. Samples taken with normal activity yielded levels of 0.2 f.mL-1. Situations involving the impact or strenuous secondary dispersal modes of contamination (dry sweeping or dusting) resulted in much higher levels of airborne fibres, 1.1 f.mL-1 to 17.7 f.mL-1.

The next three entries in Table III (19) also appear to agree with these two studies. General activity in a dormitory with exposed 98% asbestos produced average fibre levels of only 0.1 f.mL-1, whereas impact or secondary dispersal reported in other buildings produced levels all in excess of 2 f.mL-1. The use of asbestos pipe lagging in older residences with hot water heating is not uncommon and de-lagging of this piping can produce the levels shown in Table III. This is the only significant use or potential hazard in residential construction. The last three results in Table III (39) were collected in a warehouse where fallen crocidilite was widespread on the floor and fixtures. The measured fibre levels ranged from 0.26 to 11.89 depending solely on the activity level. There was still a very wide spread of individual results as shown in Table III (a factor of greater than 100 in each case).

The Advisory Committee on Asbestos (10) has also reported results based on optical microscopy from 1,102 buildings in which asbestos was thought to be present. This included buildings where the asbestos only occurred as non-friable tile or board products. Only 215 buildings were monitored as a response to a particular suspected or actual problem. Out of all these results, only 34 buildings showed airborne fibre levels above 0.05 f.mL-1. Of these buildings, 20 were in the range of 0.05 f.mL-1 to 0.08 f.mL-1; ten were in the range of 0.08 f.mL-1 to 0.2 f.mL-1; and four were above 0.2 f.mL-1. They concluded that the "general level of atmospheric dust encountered is probably higher than would emerge from a systematic survey of buildings, but it is impossible to draw any further general conclusions."

Byrom *et al.* (27) performed air monitoring in a large number of buildings utilizing various asbestos products in their construction. None of the 14 buildings containing asbestos-cement sheeting or panels showed airborne fibre levels above 0.05 f.mL-1. Two out of 30 buildings with asbestos-containing insulation board, and one out of 18 buildings with sprayed asbestos, showed levels above 0.05 f.mL-1.

The optical results reported in this section appear to indicate that optical fibre levels under normal conditions are generally quite low in buildings containing sprayed asbestos or friable asbestos block. Only in buildings containing sprayed material which is in unusually poor or exposed condition do the fibre levels appear to be significantly elevated above background levels in normal conditions. Even in these buildings low fibre levels are sometimes measured. Therefore, it does not appear possible to use optical microscopy of air samples to determine the undisturbed exposure potential in a building. This conclusion has been drawn by both the South Australian Health Commission (18) and the U.S. Environmental Protection Agency (4).

Maintenance activities around friable asbestos containing material or dry cleaning methods consistently appear to produce elevated airborne fibre levels which are readily detected by optical microscopy. None of the studies reported here used non-optical methods to identify the airborne fibres detected and therefore these results may be somewhat elevated by non-asbestos fibre. In spite of the deficiencies in optical methods, these results indicate that maintenance, alteration,and custodial work carry a greater potential for airborne fibre exposure than does simple occupancy of a building.

3.2.2 Transmission Electron Microscopy

The results obtained by optical microscopy reported in the previous section indicate that airborne fibre levels in buildings containing sprayed asbestos are usually not significantly above background values under normal building conditions. However, a large fraction of airborne fibres are not visible in the optical microscope. Nicholson *et al.* (24) concluded after

obtaining no correlation between optical microscopy and transmission electron microscopy (TEM) that only the latter was appropriate to determine asbestos fibre contamination in building air. The analytical methods of transmission microscopy have changed since the Nicholson Report and in general there is a greater range of analytical methods used in TEM. The change in analytical methods results in some apparent discrepancy between authors. Generally asbestos fibre concentrations are reported on a weight basis (nanograms per cubic metre, ng.m-3).

Results published by three different authors (11, 19, 24) are summarized in Table IV. Sebastien (11) reported results from 161 outdoor samples taken in the Paris area that showed 99% of the asbestos fibre levels were below 7 ng.m-3. It was concluded that "after a detailed study of the background of ambient asbestos levels in the metropolitan areas of Paris, it was possible to characterize as abnormally high any concentration higher than 7 ng.m-3." Sebastien and co-workers concluded that these "abnormally" high asbestos fibre levels were more common in buildings with fibrous asbestos (as opposed to cementitious material), in buildings with obvious material deterioration, in buildings with exposed material,and in buildings with a high level of activity. They were not able to develop any mathematical relationship between asbestos fibre levels, the characteristics of the material or building or the activity in the building. According to their report,"It is technically possible to determine whether a building is polluted or not after an air monitoring program employing TEM." The asbestos fibre levels in the buildings with the abnormally high fibre levels are "as high as those measured in the neighbourhood of asbestos plants where cases of mesothelioma have been reported."

The earlier results of Nicholson (24) disagree in some respects with those of Sebastien. The background levels in asbestos-free buildings range up to 42.0 ng.m-3 and in outside air up to 87.0 ng.m-3 although the average of these areas is considerably lower at 9.2 and 13.9 ng.m-3. The analytical technique used by Nicholson (the so-called rubout technique) has not been widely used but would not be expected to produce erroneously high levels in any case.

TABLE IV

Airborne Asbestos in Buildings
Analysed by Transmission Electron Microscopy

Conditions of Sample Collection	Mean Concentration $ng.m^{-3}$	Number of Samples	Range of Results $ng.m^{-3}$
ilding A, basement, exposed chrysotile, normal activity (11)	21.0	6	0.4-751.0
ilding A, tower, chrysotile in air plenum, normal activity (11)	12.0	3	3.0-28.0
ilding A, upper floors, asbestos located behind perforated panels (11)	57.0	39	0.3-630.0
uilding B, hangar, exposed amphibole and chrysotile, building not yet in use (11)	70.0	9	1.0-492.0
uilding C, chrysotile behind suspended ceiling, no air plenum (11)	0.1	3	0.1-0.2
uilding D, behind suspended ceiling, no air return (11)	3.0	4	0.6-5.0
uilding E, fibrous, exposed (11)	29.0	1	-
uilding F, cementitious, exposed (11)	19.0	4	5.0-40.0
uilding G, cementitious on structural steel (11)	2.0	3	0.1-3.0
uilding H, exposed, fibrous (11)	16.0	13	0.1-134.0
uilding I, exposed, cementitious (11)	0.4	7	0.1-2.0
uilding J, fibrous, in air plenum (11)	3.0	3	0.6-7.0
Building K, rail station, exposed, fibrous (11)	15.0	3	10.0-24.0
Building L, exposed, degrading chrysotile, painted, no air recirculation (11)	20.0	4	12.0-34.0
Building M, apartments, fibrous chrysotile, in basement garage (11)	1.0	4	0.3-2.0
Building N, apartments, fibrous chrysotile, in basement garage (11)	21.0	3	8.0-42.0
Building O, exposed, degrading acoustic (11)	20.0	4	0.4-62.0
Building P, cementitious, fully enclosed (11)	3.0	4	0.8-7.0
Building Q, cementitious, fully enclosed (11)	0.8	4	0.3-1.0
Building R, enclosed, behind suspended ceiling (11)	9.0	3	2.0-12.0
Building S, exposed, degrading acoustic (11)	0.1	3	0.1-0.1

TABLE IV (continued)

Conditions of Sample Collection	Mean Concentration ng.m^{-3}	Number of Samples	Range of Results ng.m^{-3}
Seven control buildings, no asbestos (11)	1.9	16	0.1-12.0
Outside air in twenty one locations (11)	0.96	161	0.1-9.0
Office building, cementitious, in air plenum (24)	12.0	3	2.6-17.0
Office building, cementitious, in air plenum (24)	7.0	3	2.6-11.0
University cafeteria, exposed, acoustic (24)	2.1	3	0.0-3.7
Office building, fibrous, in air plenum (24)	8.7	3	0.0-25.0
Office building, cementitious, in air plenum (24)	68.0	3	11.0-180.0
Apartment building, asbestos in spray paint (24)	8.2	4	0.7-17.0
Government building, cementitious, in air plenum (24)	2.5	4	1.2-10.0
University laboratories, exposed, acoustic (24)	41.0	6	3.7-160.00
Office building, cementitious and fibrous, on structure and deck (24)	29.0	9	0.0-55.0
Office building, fibrous (24)	29.0	6	0.6-56.0
Office building, fibrous, on beams and deck (24)	38.6	4	6.6-97.0
Office building, fibrous (24)	11.0	5	6.4-14.0
Office building, fibrous (24)	200.0	5	12.0-830.0
Office building, cementitious plaster (24)	9.5	2	0.9-18
Office building, cementitious, on columns (24)	12.0	6	1.4-23.0
Airport terminal, fibrous, coated with paint (24)	17.0	8	2.9-190.0
Gymnasium, fibrous, coated with paint (24)	27.0	6	0.9-110.0
Two control buildings, no asbestos (24)	9.2	6	0.0-42.0
Outside air, near 16 buildings above (24)	13.9	26	0.0-87.0
Office, exposed 18% chrysotile, routine activity under ceiling (19)	99.0	2	40.0-110.0
Same as above, remote from asbestos ceiling (19)	40.0	1	-
School, exposed 15% chrysotile, custodial activity (19)	643.0	2	186.0-1100.0
Apartment, chrysotile and tremolite, (19) custodial activity	296.0	1	-

Nicholson, unlike Sebastien, found no evidence that erosion of asbestos fibre occurred from decorative or acoustic materials in good condition or from cementitious sprayed material. An extremely wide range of airborne asbestos fibre levels was detected in buildings with fibrous asbestos (0.0 - 830.0 ng. m-3). Although general conclusions were drawn regarding measured fibre levels and general building conditions, no correlation was made between airborne fibre levels and material condition.

The results reported by Sawyer (19) for buildings under routine conditions also appear to be somewhat higher that most results reported by Sebastien as well. It is clear once again that monitoring performed during custodial activity shows very elevated asbestos fibre levels compared to samples taken during normal activity.

The combined results of these workers, therefore, while indicating that buildings containing sprayed asbestos often have higher than background levels of airborne asbestos, cannot be used to determine potentially hazardous buildings. The measured air levels are indicative only of the fibre levels at the precise time of sampling and hence are quite variable even within one building. The elevated fibre levels during maintenance detected by optical microscope are also detected as elevated asbestos fibre levels by TEM.

The results reported above will be supplemented in a later chapter with results obtained by Chatfield and Dillon in Ontario buildings. An attempt to systematically correlate their results with visual observations will also be made. Their results to date (20) appear to indicate that transmission microscopy even in buildings with fibrous asbestos are unpredictable and often not significantly above background. These results may have a bearing on the selection of the appropriate corrective action.

4. HAZARD ASSESSMENT AND SELECTION OF CORRECTIVE ACTION

The importance of secondary contamination in determining airborne asbestos concentrations has been pointed out in the previous section. It is clear, however, that a necessary condition for contamination is the prior release of asbestos from the asbestos-containing material by fall-out, erosion, or impact. Therefore, in theory, it should be possible to evaluate the potential for fibre release by considering the condition and physical characteristics of the asbestos-containing material. Although the airborne fibre levels reported in the previous section showed no quantifiable relationship with visual observations, there is obviously some relation between these. The factors of importance in determining fibre release from a surface and various indices used to rate these factors will be considered in this section, along with a discussion of remedial routes available.

4.1 Factors in Hazard Assessment

The factors identified by the U.S. Environmental Protection Agency, (4, 21) which are important in determining the potential for fibre release in school buildings are as follows:

(a) Condition of Material: Material condition indicates the extent of contamination and the likelihood of future contamination. This factor is a combination of quality of installation, adhesion of the friable material to the underlying surface, material deterioration, and damage. Delamination or deterioration of the material depends on the characteristics of the material itself (whether it shows signs of aging or loss of cohesive strength). Damage is incurred by either accidental or intentional contact. Evidence of debris can be a good clue to the condition of material, which may vary from minor deterioration and damage to widespread and severe material disintegration.

(b) Water Damage: Water can dislodge, delaminate, and disturb asbestos materials that are otherwise in excellent condition. Water can carry fibres in the slurry to other areas in the building where evaporation

will leave a collection of fibres that can become re-suspended in the air. Water damage will have a significant effect on selection of a corrective method, essentially eliminating certain types of sealants.

(c) Exposed Surface Area: The exposed surface area of friable material has an effect on potential fibre fallout levels and the possibility for contact and damage. A useful criterion to apply for this factor is whether the friable material is visible.

Asbestos material above suspended ceilings is not considered as exposed. However, if the ceiling panels are removed for routine maintenance activities above the suspended ceiling or are damaged due to vandalism, the asbestos material should be considered as exposed in that area. Areas with louvers, grids, or other open ceiling systems should be considered as exposed. However, exposed does not mean accessible, which is a separate factor.

(d) Accessibility: If the material can be reached, it is accessible and subject to accidental or intentional contact and damage. Accessibility is a good indicator of possible future exposure caused by contact and damage. This factor should also include some consideration of the proximity of friable material to heating, ventilation, lighting, and plumbing systems requiring maintenance or repair.

The behavior characteristics of the student population should be considered in evaluating accessibility. For example, students involved in sports activities may accidentally cause damage to asbestos materials on the walls and ceilings of gymnasiums. Material that is easily accessible is also subject to damage by vandalism.

(e) Activity and Movement: This factor combines the effects of general causes that may result in contact with, and damage of, friable material. These causes include air movement, building vibration from machinery or any

other source, and activity levels of students or building workers. This factor is also an indicator of future exposure potential. Its value will be low in school libraries, offices, and most classrooms; moderate in some classrooms and in school corridors; and can be exceedingly high in gymnasiums and cafeterias.

(f) Air Plenum or Direct Air Stream: Friable asbestos material contained within an air plenum or in an air stream, if undisturbed, has very low potential for contaminating the building environment. However, it must be considered since contact and damage may occur during maintenance, repairs, and renovation. In dealing with asbestos material located in air plenums, special attention should be given to a management system described in Section 5.

(g) Friability: The asbestos materials can vary in their degree of friability. The more friable the material, the greater the potential for asbestos fibre release and contamination. Sprayed asbestos material is generally more friable than most troweled materials.

(h) Asbestos Content: The percentage for all the types of asbestos present should be added for the total asbestos content. With a high percentage of asbestos, there are more fibres that can be released and contaminate the building environment.

These factors are largely subjective and depend on the judgement of the person or persons performing the inspection.

The techniques of performing an inspection, deciding on the particular factor, and methods of bulk analysis have been described in detail elsewhere (4, 15, 19, 26) and will not be covered in this study.

Other factors can be also taken into account. The Toronto Board of Education adds an additional factor depending on whether chrysotile or amosite is present in the asbestos-containing material (21). (No crocidolite was identified in the buildings in their jurisdiction.) A higher factor is assigned to an installation containing amosite which reflects the stricter proposed Ontario occupational exposure standard for amosite (23).

The United States Navy has developed a risk index (15) which, in addition to the factors included by the Environmental Protection Agency, also considers the number of occupants in an affected area and the duration of occupancy in that area. This is the only known rating index which attempts to consider the building occupancy in a quantitative fashion.

4.2 Exposure Hazard Indices

Although the factors listed above are largely subjective, a number of algorithms which mathematically combine various factors into a single exposure risk factor have been developed. The most widely known was published in draft form by the Environmental Protection Agency in 1979 (21). It is included here as Appendix A. The Ferris Index (named after Dr. B. Ferris, who developed the scale) was used to rate the potential contamination in Massachusetts public schools (25). The Toronto Board of Education has used a modified Ferris Index, mentioned earlier, on all schools in its jurisdiction using a single inspector to maintain uniformity. The scale is included here as Appendix B. The U.S. Navy Risk Evaluation Index (15), also mentioned earlier, is included here as Appendix C. This index incorporates physical observations of the material and installation (friability, accessibility, condition,and activity in the area) with the percentage of asbestos to produce a single level of exposure factor. These factors have an extremely large spread from 0.0002 to 470,000.

The Ferris Index, Toronto Board of Education Index, Environmental Protection Agency Exposure Algorithm, and the U.S. Navy Risk Evaluation Index all produce a single number which in some way should theoretically express the relative hazard of the particular installation. In addition, all of these, except the

Toronto Board of Education Index, specify a particular appropriate action or range of actions which should be undertaken for an installation with a particular rating. Although the factors which make up these indices are obviously important in determining airborne fibre levels, there as yet has been no evidence put forward to correlate these indices with airborne fibre levels. Therefore, the indices, while providing a satisfactory method of comparing a number of different installations, should be used with caution. They should not be used to determine appropriate remedial action or whether remedial action is required without taking into account other non-quantifiable factors.

As pointed out in Section 3.2, cleaning and maintenance activities have a major influence on determining airborne fibre levels in a building. Therefore, the care exercised by the maintenance staff of the building, cleaning methods used in the building, and the ability of the building management to control outside contractors working in the building (telephone, telecommunications, etc.) will have a marked influence on the selection of remedial action. Although these factors can be partially accounted for under the level of activity factor in the indices, the data in Section 3.2 implies that they should be considered separately.

These rating factors will be compared with transmission electron microscope visible fibre levels in a later chapter of this study. This will be important in determining whether in fact there is a correlation between the measured levels and the indices.

4.3 Selection of Asbestos Control Procedure

Once friable asbestos-containing material has been identified in an area, some form of control action must be taken. The procedures which have been used to date fall into one of the following categories:

(a) Management and custodial control (or deferred action): Asbestos is left as in the building. Procedures are established to reduce or minimize any potential fibre release.

(b) Enclosure: asbestos-containing material is enclosed behind a solid barrier.

(c) Encapsulation: asbestos-containing material is coated with a bonding agent or sealer.

(d) Removal: Asbestos material is removed and disposed of by burial.

The first of these options -- management and custodial control — should always be instituted once friable asbestos material has been identified in a building. It may be merely a temporary precaution taken before one of the other options is implemented or it may be an acceptable long term means of preventing any potential exposure to airborne asbestos.

The advantages and disadvantages of each of these methods have been summarized in an Environmental Protection Agency publication (4). This is reproduced here as Table V. Several additional points not covered in the original table have been added. Each of the methods will be discussed separately below.

Although Table V covers most of the physical factors determining which of the control measures is appropriate in any installation, usually other factors are used for the choice of option. Employee, newspaper, or public pressure have often resulted in clearly unnecessary or inappropriate work being performed. This will hopefully decrease as a more rational or cautious approach is adopted. Consideration of the future use of the building is a very important factor. That is, if a building is to be renovated shortly, a management system could delay removal so that removal and renovation can be performed together. If major renovations are to be performed, then usually removal becomes the safest and most economical corrective action.

The control which a building owner has on the tenants of the building is a very significant factor. If tenants of a building cannot be prevented from disturbing the material, then management and custodial action is usually inappropriate unless the product has a very low potential of fibre release. Economic factors are also of major concern in selecting a corrective action

TABLE V

SELECTION OF APPROPRIATE CORRECTIVE ACTION

Method	Advantages of Method	Disadvantages of Method	When Method is Appropriate	When Method is Inappropriate
Management and custodial control/ deferred action	No direct cost	Potential for exposure may increase Management system required. Precautions necessary to prevent damage during maintenance or renovation Continuing inspection and reevaluation necessary	Negligible exposure potential As an interim measure prior to implimentation of other corrective action	Definite or questionable exposure potential Continuing inspection doubtful
Enclosure	Controls exposure potential May be most rapid, economical, uncomplicated method in some installations	Asbestos source remains Fiber fallout continues behind enclosure May be costly if other systems disturbed (e.g., lights) Management system required. Precautions necessary for entry into enclosure for maintenance or renovation Continuing inspection required to check for damage to enclosure system Maintenance on damaged enclosure system required	Removal not feasible Disturbance or entry into enclosed area not likely Economic advantage Building condition allows installation of barrier	Removable feasible Damaged or deteriorating material causing high levels of fiber fallout Water damage Damage to enclosure likely Entry into enclosure probable for repairs and maintenance Continuing inspection and maintenace of enclosure doubtful

TABLE V (continued)

SELECTION OF APPROPRIATE CORRECTIVE ACTION

Method	Advantages of Method	Disadvantages of Method	When Method is Appropriate	When Method is Inappropriate
Encapsulation	Controls exposure Potential	Asbestos source remains	Removal not feasible	Removal feasible
	Usually most rapid and economical method	If material is damaged or deteriorating, additional weight of the sealant may cause delamination	Material still retains bonding integrity	Material does not adhere well to substrate. Weight of sealant may cause delamination
	Some thin acoustic materials can be fully penetrated by sealant and rendered non-friable		Damage to material not probable	Material is deteriorating or damaged
		Management system required. Precautions necessary to prevent damage during maintenance or renovation.	Limited accessibility of material	Damage to material probable
			Complex surfaces to be covered	Water damage
		Continuing inspection required to check for damage to encapsulated surface	Economic or time advantage	Continuing inspection and maintenance of encapsulated material doubtful
		Maintenance on damaged or deteriorating encapsulated surface required		
		Encapsulated material is difficult to remove later (if necessary)		
		Encapsulant may affect fire rating of material		

TABLE V (continued)

SELECTION OF APPROPRIATE CORRECTIVE ACTION

Method	Advantages of Method	Disadvantages of Method	When Method is Appropriate	When Method is Inappropriate
Removal	Eliminates asbestos source Ends exposure potential	Usually most costly and complicated method Usually most time consuming method Replacement with substitute material may be necessary Removal usually performed wet to reduce fibre levels. Water may damage building fixtures If removal performed dry then extremely high potential for worker exposure	High exposure potential Material is deteriorating or damaged Material is accessible Flat, open material surface	Removal is not feasible because of cost, location of material, and kind of surface to which material has been applied (e.g., removal of material from complex surface such as pipes, lines and ducts)

since typical costs might range from almost zero for management to twenty dollars per square foot for the most difficult removal and replacement. These factors must all be considered by the building owner for the particular building but the physical factors in the selection of corrective action will be chiefly discussed here.

4.3.1 Management and Custodial Controls

This option, which is also referred to at times as deferred action, is appropriate in cases where the potential of airborne fibres is low and a procedure for controlling or monitoring future exposure can be established. It is the method which is usually selected for friable pipe insulation or for undegraded cementitious materials. The chief advantage of this option is that it results in a minimal direct cost to the building owner. It does require the establishment of a management procedure and the training of maintenance workers.

If renovations or demolition are to be undertaken during which the friable material will be extensively disturbed and result in elevated fibre levels, then at that time one of the other control options must be selected. For this reason, the term 'deferred action' is sometimes used to describe this option. In any building where one of the other control options is to be used, management and custodial control should be used as an interim measure. The procedures required to institute this option effectively are described in Section 5.

4.3.2 Enclosure

Enclosure is the least commonly selected means of corrective action. It has the major disadvantage of leaving the asbestos-containing material in the building. It is, therefore, necessary to provide some form of management and continued surveillance. The method, while usually less expensive than removal, is still relatively expensive. The installation of the barrier can also result in high airborne fibre levels. In addition, not all installation of asbestos-

containing material can be enclosed due to the location of the friable material and space limitations. It is most commonly used in areas where some action is called for due to the condition of the asbestos-containing material, but neither encapsulation nor wet removal are feasible.

4.3.3 Encapsulation

Encapsulation is a widely used method of asbestos control. The asbestos-containing material is sprayed with a bonding agent called a sealer or encapsulant. Two types of sealers exist: penetrants penetrate into the asbestos-containing material and harden the material; bridging sealers produce a continuous tough impermeable coating on the surface of the asbestos-containing material. The method of performing this corrective work is covered in Section 6.

Encapsulation should be limited to areas where contact damage will not occur subsequent to the application of the sealer. It is also important that the asbestos material to be encapsulated possess sufficient strength and adhesion to the substrate to support the additional weight of sealer. Since the sealers are all water based, the asbestos-containing material can become loosened when the sealer is applied. The asbestos-containing material remains in the building and therefore should be routinely inspected. It is also important that sealants which are used over fireproofing should not adversely affect the fire rating of the structure. This is an often overlooked aspect in the selection of this option.

4.3.4 Removal

If the condition of the buildings or the asbestos-containing material warrants some remedial action beyond management and custodial control, then removal is the corrective action most commonly chosen. Although this route is usually the most expensive, it has the major advantage of permanently removing the asbestos-containing material and resolving any potential problem. No further special precautions need be followed by building personnel.

If this work is improperly performed, there is a very great risk of contamination of the rest of the building, but this is true of all corrective actions and will be addressed in Section 6. The asbestos-containing material is generally removed wet to reduce fibre generation and is removed from the site in a sealed container. In Canada only Saskatchewan (31) considers asbestos to be a hazardous chemical substance and asbestos waste therefore can be disposed of at any sanitary landfill which will accept it in all other provinces in Canada including Ontario. In most buildings the removed asbestos-containing material must be replaced with asbestos-free material which also increases the total cost.

5. ASBESTOS MANAGEMENT IN BUILDINGS

Once a friable asbestos-containing material is identified in an area, a program of management should be instituted to reduce any potential exposure to asbestos fibre. This management programme, under which maintenance, repair, and normal custodial duties are strictly controlled, may be a temporary measure prior to removal, enclosure or encapsulation of the asbestos-containing material. In many relatively stable installations, the use of a management programme is sufficient for long-term control of any potential exposure to airborne fibre. Techniques of performing custodial work (cleaning, etc.) and minor maintenance work will be covered in this section.

5.1 Custodial Measures

Sawyer (9) has described the effect of various methods of performing custodial work in a particularly contaminated library. The conditions in this building, which were described in Section 3.2.1, obviously indicated the need for removal of the asbestos-containing material. The management procedures were therefore instituted as a temporary measure prior to removal. The effects of various cleaning operations are summarized in Table VI.

TABLE VI

Effects of Various Custodial Activities On Measured Airborne Fibre Levels (Personal Samples, NIOSH Procedure)

Custodial Activity	Fibre Counts (f.mL-1)	Number of Samples
Dry dusting, above waist level	4.0	6
Wet cleaning, above waist level	0.3	4
Dry sweeping, below waist level	1.6	5
Wet mopping, below waist level	0.2	4
Sample collected 20 ft. from dry cleaning	0.3	6
Dry dusting of books	4.02	6
Vacuuming books with high efficiency particulate absolute vacuum	0.4	8
Damp wiping of shelves	0.2	4

These data indicate the significant reduction in fibre levels which is possible using either wet techniques of cleaning or a high efficiency particulate absolute (HEPA) filtered vacuum. These vacuums contain a filter which is certified to filter particles down to 0.3 micrometres with a minimum efficiency of 99.97%. This is a level of filtration far superior to a non-HEPA vacuum.

The conscientious use of these modified cleaning methods reduced airborne fibre levels by a factor of eight or more. In a building where the contamination is of a less serious nature due to a more stable asbestos containing material, the use of these techniques can reduce the measured airborne fibre levels to background levels. In addition, any potential bystander exposure (shown in Table VI as exposure at 20 feet from the worker) can be reduced or prevented by scheduling the work when the area is unoccupied.

The wet cleaning methods or HEPA vacuum will effectively remove a significant part of the accummulated asbestos fibre-containing dust from the building and the asbestos fibre levels will be reduced for some time after this. The wet cleaning or HEPA vacuuming must be performed on a regular basis, but normal cleaning methods can be used between these occasions. The frequency of the wet cleaning or HEPA vacuuming cannot be easily defined, however, and depends on the factors described in Section 4.1.

The U.S. Navy (32) has adopted the hygiene practices developed by the Asbestos Research Council (33) for cleaning of facilities containing friable asbestos materials. These guidelines are attached as Appendix D. The recommendations, which are largely for an industrial type of building, can be summarized as follows:

(a) FLOORS: Remove visible contamination by regular cleaning with a dustless method, preferably with a HEPA vacuum. Alternative methods include wet mopping or chemically impregnated mops. The cleaning equipment should be used only for asbestos-related work and treated appropriately.

(b) WALLS: Annual cleaning with a HEPA vacuum or wet cleaning.

(c) MACHINERY AND EQUIPMENT: Remove visible contamination by cleaning with HEPA vacuum or wet method.

(d) OVERHEAD PIPES OR EQUIPMENT (not behind suspended ceiling): Clean annually or when visible dust has accumulated. This should be done with a HEPA vacuum or wet methods and the cleaners should wear protective masks and clothing.

These above recommendations can be adopted for any specific building where friable asbestos is found and not yet enclosed, encapsulated, or removed. Bystander exposure should be kept to a minimum by scheduling the work for a time when the building has a minimum number of occupants. This timing is not usually a change from normal custodial activity.

5.2 Minor Maintenance

The results reported in Section 3.2.1 indicate the importance of impact during during maintenance on airborne fibre levels. For any programme of management and custodial control to be effective, certain procedures must be followed in minor maintenance where asbestos fibres may be liberated. The general techniques have been described elsewhere (34) and training courses have been established to instruct maintenance employees in this work (35).

The procedures follow the general guidelines:

(a) enclose the work or work area ;

(b) protect the worker;

(c) minimize fibres in the air;

(d) use correct clean-up and disposal methods.

The way these guidelines are applied in practice will vary depending on the type of work, location of work, and the likelihood of fibre release to the air. These guidelines will apply to all work in contact with friable asbestos or behind any barrier which hides a friable asbestos product such as a suspended ceiling.

Enclosing the work or work area will reduce the spread of fibres to the surrounding area. Although the fine fibres cannot be easily enclosed, larger particles or lumps should be confined to the work area by the enclosure. If the work is relatively extensive in an occupied area or has a risk of disturbing a significant amount of asbestos-laden dust, the enclosure may be quite elaborate and well sealed. In other instances, a drop sheet adequate to prevent any lumps of asbestos falling to the floor can be acceptable if combined with procedures to minimize dust generation.

The results presented in Section 3.2.1 indicated that the worker may generate high local fibre levels. Therefore, the worker should be equipped with an appropriate asbestos approved mask and protective clothing (usually disposable) to prevent contamination of personal clothing. The worker should be instructed in the correct use and maintenance of this equipment.

Airborne fibres can most effectively be minimized by working only with material that has been wetted prior to disturbance. Sawyer (9) has shown that airborne fibre levels can be reduced when material is wetted before disturbance. Often a surface active agent is added (9, 19) to the water to aid penetration and this has been shown to further reduce airborne fibre levels. A second method of reducing the airborne fibre levels is by vacuuming surfaces with a HEPA vacuum. This is particularly important on the top of suspended ceiling tiles.

At the completion of the minor work, the area and any contaminated equipment should be properly cleaned using the techniques described in Section 5.1. The asbestos contaminated material should be sealed and correctly disposed of. If a substantial quantity of asbestos-containing waste is generated, then provincial guidelines (36) must be followed in disposal.

Ideally, work should be performed outside normal working hours to reduce the number of bystanders. All personnel other than the maintenance personnel should be denied access to the immediate work area. If work is to be performed above a suspended ceiling below sprayed asbestos-containing material, the South Australian Health Commission (34) has recommended either one of two procedures be followed. The first procedure is described as follows:

(a) The work shall be carried out when the room concerned has been vacated and the air conditioning or other forced ventilation system turned off.
(b) The floor and the furniture within a 4-metre radius of the ceiling opening shall be covered with plastic sheeting sealed along joints with masking tape or a similar material.
(c) The first tile shall be lifted carefully, so as to minimize the amount of dust spilled off it. Before further work is carried out, the tops of any additional tiles which are to be removed, and the tops of adjacent tiles, shall be thoroughly vacuum cleaned.
(d) After the work is completed and the ceiling tiles are back in place, the

workers shall decontaminate themselves by vacuum cleaning their outer clothing. Their ladder, tools, etc. shall also be vacuum cleaned.

(e) The floor, walls, furniture, and fittings within a 4-metre minimum radius of each ceiling opening shall be thoroughly vacuum cleaned before allowing unprotected personnel to enter the room and before the air conditioning or ventilation system is again turned on.

The second acceptable procedure is as follows:

A floor-to-ceiling enclosure, constructed from a lightweight frame covered with heavy-duty plastic sheeting and with an integral floor sheet shall be used as a portable enclosure. The method of operation shall be as follows:

(a) The enclosure shall be erected under the tiles to be removed and sealed at the ceiling and at the base. Access to the enclosure shall be so organized that the workmen can seal it off from the inside and the enclosure shall be as airtight as possible when so sealed off.

(b) If ventilation air either enters or leaves the enclosure, then the ventilation system shall be either turned off completely or that part of it isolated.

(c) The equipment to be used (vacuum cleaner, step ladder, tools, etc.) shall be placed inside the enclosure.

(d) The workmen, suitably protected, shall enter the enclosure, seal it off, and carry out the work.

(e) When the work is completed and the ceiling tiles back in place, the inner walls, floor, and ceiling of the enclosure, all the tools and equipment, and the workmen themselves shall be vacuum cleaned.

(f) The enclosure can then be dismantled.

A draft specification for asbestos pipe covering removal or other minor sprayed fireproofing removal from Public Works Canada, Ontario Region, is attached as Appendix E (44). These are typical of the simplified specifications

used in small removal operations. The wetting technique described in Section 7.2 of the specification is somewhat unusual as normally the material must be wetted with a fine spray of water instead. It must be stressed that this type of specification is not sufficient for large removal jobs. The separation between large and small jobs is left to the discretion of the owner or specification writer at the present time. Specifications for large scale work will be presented in the next section.

In order to ensure that these procedures of minor maintenance and custodial control are followed, a system of notification of work must be established in the building. All work should be cleared in writing through a single person or office. This applies equally to maintenance employees of the building, any contractors hired to perform work in the building, and any others performing work which may disturb friable material or settled asbestos fibre. This obviously includes any telephone or telecommunications wiring above suspended ceilings. The difficulties in ensuring the continued use of the correct procedures often results in one of the other control options being selected. The visible precautions required to ensure safe performance of the maintenance work and protection of the workman can also cause undue alarm in the general occupants of the building. Therefore, in order to allay these understandable fears, the general building occupants must be informed of the procedures to be followed and convinced of their effectiveness.

6. PROCEDURES FOR CORRECTIVE MEASURES

The remaining asbestos control options, removal, enclosure, and encapsulation have been widely used in many countries including the United States (9, 19), Britain (37), France (11), and Australia (38). The experience gathered in asbestos abatement operations in these countries has been drawn on in preparing specifications for use in Canada. The asbestos abatement work has now reached a stage where guide specifications are either published or in a draft form suitable to be applied to almost any asbestos control project. Three examples of these guide specifications are included here as appendices. There are some differences between these specifications which will be discussed but there is general agreement on the procedures for performing corrective measures. The differences between specifications will be discussed and commented on in the next section.

6.1 Specifications for Corrective Measures

The three specifications for major work are as follows:

Appendix F - Public Works Canada (PWC) Asbestos Abatement Specification (45);

Appendix G - Metropolitan Toronto School Board Specification for Removal of Asbestos Coating (46);

Appendix H - Foundation of the Wall and Ceiling Industry (FWCI) Guide Specifications for the Abatement of Asbestos Release from Spray or Trowel-Applied Materials in Buildings and Other Structures (47).

All three of these specifications cover asbestos removal, but only the Public Works and FWCI methods cover encapsulation and enclosure. These two describe asbestos abatement work in more detail than the Board of Education method which has been simplified considerably. The FWCI guide specification is an updated version of the U.S. Environmental Protection Agency Guide Specification (19) and encompasses their recommendations. The procedures for asbestos abatement work are outlined in good detail in the Public Works Canada Specification. The procedures, precautions and work practices which are described there will only be commented upon here. The main sections of the specification are outlined in Table VI.

TABLE VI

Public Works Canada, Asbestos Abatement

1. General
   - 1.1 Outline of Work
   - 1.2 Definitions
   - 1.3 Regulatory Agencies
   - 1.4 Submittals
   - 1.5 Existing Conditions
   - 1.6 Worker Protection
   - 1.7 Visitor Protection
   - 1.8 Notification

2. Products
   - 2.1 Materials

3. Execution
   - 3.1 Preparation
   - 3.2 Asbestos Removal
   - 3.3 Asbestos Sealing
   - 3.4 Asbestos Enclosure
   - 3.5 Clean-up
   - 3.6 Re-establishment of Objects and Systems
   - 3.7 Air Monitoring

Section 1.1 indicates that the specification is applicable to removal, sealing (encapsulation), or enclosure of spray or trowel applied asbestos-containing material. The definitions in Section 1.2 are in considerably less detail and are less numerous than in Section 1.3 of the FWCI Guide. The FWCI Guide provides a good common language base for the asbestos abatement work. The regulatory agencies described in Section 1.3 cover provincial, federal, and local levels and specify that the most stringent requirements should be followed. Unlike the U.S. regulation spelled out in Section 1.4 of the FWCI Guide, no regulations are specifically named. The submittals required before commencing work are outlined in Section 1.4. The existing conditions in the building are outlined in Section 1.5. Worker protection is covered in detail in Section 1.6. This is an extremely important section of any asbestos abatement project. The PWC guide specifies the use of disposable work overalls. This has been generally interpreted to mean a single-use disposable coverall (such as a spun polyolefin), but as the FWCI Guide makes clear in Section 1.6, re-usable clothing can be safely used if it is not taken from the work area. This generally will make workmen more comfortable and efficient in the work site. Visitor protection which is included in the personnel protection section of the FWCI Guide is covered separately in Section 1.7 of the PWC specification. Notification of federal and provincial agencies is described in Section 1.8.

Section 2 describes products to be used in the contract. This includes materials, tools, and equipment which are described separately in the FWCI Guide.

Section 3 covers in detail all phases of preparation, performance, and clean-up for removal, sealing, or enclosure of asbestos. The three specifications provided agree closely on all aspects of the contract performance to the time that clean-up of the area is required. The PWC specification calls for the following clean-up procedure:

(a) After removal of gross contamination, wet clean the work area, leave all plastic sheeting in position.

(b) Wait 24 hours and wet clean again.

(c) Wait 24 hours and vacuum the area with a HEPA vacuum followed by wet cleaning.

(d) Fog the area, perform air sampling, and if satisfactory, remove the plastic and ensure the area is completely clean by washing if necessary.

The Metropolitan Toronto School Board Specification is very similar to the PWC specification. The very recent FWCI Guide describes the same process as follows:

(a) After removal of gross contamination, wet clean the work area.
(b) Remove the plastic sheeting from floors and walls, but leave over windows, doors, decontamination chamber, etc.
(c) Clean all surfaces with water or a HEPA vacuum.
(d) Wait 24 hours and clean again with water or a HEPA vacuum.
(e) If a final inspection shows the area is free of visual dust, then the plastic can be removed completely and the area wet cleaned. If visible dirt can be seen, then the cleaning must be repeated.

The difference in these methods is principally in the order of clean-up and removal of the plastic barrier. The PWC method has the disadvantage that some asbestos will be trapped behind the plastic on the floors or walls and not properly cleaned. The FWCI Guide removes the plastic at an early stage of clean-up and exposes the walls and floors to an extremely contaminated room. A combination of these two procedures appears to the author to be superior to either of these methods as written. The clean-up would be as follows:

(a) After removal of the gross contamination, wet clean the work area, leave all plastic sheeting in position.
(b) Wait 24 hours and wet clean again.
(c) Remove the plastic from walls and floors.
(d) Wait 24 hours and clean again with water or a HEPA vacuum.
(e) If a visual inspection shows the area free of dust, or an air sample is suitable, all remaining plastic can be removed.

Both the Toronto School Board specification and PWC specification specifically call for air monitoring (Section 3.7 of the PWC specification). The FWCI Guide does not specifically call for air monitoring as experience has shown visual inspections to be more rigorous. The PWC method describes an area as properly cleaned when, under simulated conditions of normal use, the airborne fibre count is 0.10 f.mL-1 or less. An acceptable level is not mentioned in the other two specifications. It has been the author's experience that a visual inspection is a more severe test of the effectiveness of removal and clean-up; however, either method of inspection is likely sufficient.

6.2 Alternate Methods

A number of alternate methods of performing asbestos abatement work, particularly removal, have been developed. The use of a high efficiency particulate absolute (HEPA) filtration system is allowed under the FWCI Guide specifications (Section 2.2.1.1) to provide a negative pressure in a work site providing the equipment is operated continuously until decontamination is complete. This type of vacuum system has been used in projects where a further reduction in fibre levels in the work area was required. A number of companies have extended this use of a vacuum in the work area to use a truck mounted vacuum system to provide negative pressure or to provide a powered means of removing the asbestos containing waste. The powered removal methods have been evaluated in a EPA report "Evaluation of a Commercial Vacuum System for the Removal of Asbestos" (40), using both wet and dry techniques. The machine evaluated incorporated a HEPA filter and the results obtained showed very low fibre levels in the work site, in the rest of the building, and in the exhaust air from the truck filter. The material was hand scraped and the waste carried away by the vacuum system. There were some problems encountered in dismantling the unit and in disposal but these were not insurmountable. No information was provided on relative cost of the power waste removal versus the manual methods described in Section 6.1.

At least five companies operating in Canada are presently using or developing systems similar to the system evaluated in the EPA test. In addition several of these firms are combining the powered waste handling aspect with a water jet or water-sand slurry to scrape the material off the substrate. None of the systems in use in Canada incorporate a HEPA filter in the vacuum system but preliminary tests of fibres escaping from a typical unit show that the filtration may be adequate (41). Tests performed to date have produced rather mixed results as to the efficiency or cost-effectiveness of these systems (42). This power method may have applications in large open areas such as garages or hangars if approved by appropriate regulatory agencies. One firm operating in Western Canada reports good success in work areas with restricted access or where electrical hazards eliminate standard wet removal methods. The removal trucks have been licensed as portable asbestos plants in Alberta (43).

7. CONCLUSIONS

The information presented in this chapter indicates that in the jurisdictions discussed (the United Kingdom, the United States, France, and Australia) there has been concern expressed over the potential for exposure to airborne asbestos in buildings. The concern has centred on friable asbestos-containing materials used in construction.

Air monitoring data from these countries indicate that the mere presence of friable asbestos-containing materials in a building does not necessarily produce airborne fibre levels in excess of normal background levels. There has been no direct correlation found between measured fibre levels and visual observations of the asbestos-containing material. Only if friable materials are exposed and in poor condition are measured fibre levels under normal or quiet conditions likely to be significantly above background. In many installations, however, janitorial or maintenance activities near or on friable asbestos-containing materials may result in fibre levels above occupational exposure standards. Therefore in these instances careful custodial measures must be enforced to minimize exposure of these workers and other building occupants. The necessary steps for a programme of management and custodial control are described here.

If the asbestos containing material is exposed and in poor condition, if the material is to be disturbed by renovations or demolition, or if careful management custodial control can not be guaranteed, then more radical control options may be appropriate. Techniques for removing, enclosing, or encapsulating the asbestos-containing friable materials have been developed and are described in this chapter. The need for these measures, cost of the measures, and effectiveness of them will be discussed in later chapters of this study. These will be based largely on data specifically collected for the Royal Commission on Asbestos.

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CHAPTER 2

CURRENT PROGRAMMES OF INSPECTION AND CONTROL

1. INTRODUCTION

In Ontario, public recognition of possible adverse health effects due to the presence of asbestos in public buildings dates from July 1979 (1). The development of the public concern over the presence of asbestos, particularly in schools, has been addressed in another research study prepared for the Royal Commission on Asbestos (2) and will not be discussed here in detail. This public awareness was more recent by a decade than the first speculation on the danger of airborne asbestos to the occupants of buildings incorporating asbestos in their construction (3). In recognition of this general public concern, a number of programmes of inspection and control have been initiated in Ontario. The purpose of this section is to briefly discuss the inspection and control programmes undertaken in other jurisdictions, particularly the United Kingdom and the United States, and to identify typical programmes now underway or completed in Ontario.

2. DEVELOPMENT OF CONCERN AND CONTROL PROGRAMMES

2.1 The United Kingdom

Concern over the possibility of asbestos fibre contamination in buildings dates from the late 1960's in the United Kingdom. Although this first study by Byrom *et al.* (3) concluded that the presence of asbestos-containing building materials did not constitute a hazard to the health of building occupants, later work of Lumley *et al.* (4) reported much higher airborne fibre levels that did cause concern. As a result of this and other studies, the United Kingdom Ministry of Defence had decided as early as 1971 to seal sprayed asbestos-containing insulation in storehouses and to provide means of protecting the sealed insulation from damage(4). By 1974 the Sub-Committee of the Joint Advisory Committee on Safety and Health in the Construction Industries had issued a report (5) which stated that demolition of a building containing either sprayed asbestos or pipe insulation containing asbestos posed a health hazard to workmen unless

precautions were followed.

In spite of these early concerns in the United Kingdom, there was no move at that time to stipulate any general program of inspection and control in buildings. More recently the Advisory Committee on Asbestos (6,7) has concluded that the non-occupational risk is not sufficient to warrant a recommendation for general removal of asbestos from existing buildings. The Committee further indicated that it was primarily the responsibility of contractors to ensure the safety of their own workmen engaged in repair, demolition,or removal of asbestos-containing material. Therefore no recommendation was made that universal identification of asbestos in buildings be made compulsory. The recommendations contained in these reports of the Advisory Committee are currently being put into regulations (8). These regulations put a statutory ban on the future use of asbestos sprayed coatings and embody a requirement for employers and self-employed persons to be licensed by the Health and Safety Executive before undertaking work involving asbestos insulation or asbestos coatings. This would include all phases of asbestos abatement in buildings. The very high level of awareness of British workers involved with asbestos insulation or sprayed asbestos coating (9), licensing requirements,and mobile inspectors generally ensure that work involving friable asbestos is properly identified and inspected (in spite of the lack of universal programmes of identification). A large number of building owners in the public and private sector have undertaken complete asbestos surveys of their buildings even though this is not required by any legislation. A trade organization, the Asbestos Removal Contractors Association has also been established to encourage better work practices and provide a professional forum for contractors working in asbestos removal.

2.2 The United States

The occupational health hazard posed to insulation workers in the United States was the subject of numerous investigations in the 1960's. Selikoff and co-workers (10,11) investigated the medical aspects of this exposure and typical airborne fibre levels detected during spraying of asbestos. The measurement of asbestos in the vicinity of these sites showed environmental asbestos concentrations to exceed those of background by more than 100 times (12). The concern over possible health effects

on urban populations led various jurisdictions (New York, Boston, Philadelphia, Illinois) to ban its use in the early 1970's. In 1973, the U.S. Environmental Protection Agency imposed a nation-wide ban on the spray application of insulating or fireproofing material containing more than one percent asbestos by weight (13). This prohibition on spraying was extended in 1977 to include all materials containing more than one percent asbestos (14). As early as 1971 the concern over asbestos exposure in specific buildings led to air sampling (15) and by 1974 some removal of asbestos had been performed (16). A U.S. E.P.A. study published in October 1975 (47) presented results on nineteen buildings which indicated that "significant asbestos contamination can occur in the air supply system of buildings" containing sprayed fireproofing, decorative, or acoustic materials.

The growth of public concern was occurring during this same period and has been traced in some detail elsewhere (2). A number of state and local school boards began to take remedial action. The U.S. E.P.A. surveyed these boards and began to provide assistance in early 1979 in the form of a nation-wide information and technical assistance programme (17). The voluntary programme of identification and notification of the presence of asbestos in schools was shown to be ineffective and a mandatory programme was adopted on January 16, 1981 (18). No funding has yet been appropriated to support this legislation.

The programme of asbestos identification and control in the U.S. has been concentrated in the school system. Recently this concern has spread to various agencies of the federal government (19), but to date there has been no mandatory programme adopted in either the public (excluding schools) or private sectors. The asbestos abatement programme has also been affected by the recent economic slow-down and cuts in government spending (20).

Under the terms of the 1977 Act (14) there is a requirement that the administration of the U.S. E.P.A. or an authorized representative shall be notified in writing at least ten days prior to commencement of any asbestos removal work. This section has generally been used to control work in buildings other than schools since the EPA has the respons-

ibility to ensure that correct work methods are used. This effectively serves a similar function as the licensing of contractors in Britain. The health of workers in asbestos control projects is the responsibility of the Occupational Safety and Health Adminstration and is protected under the Code of Federal Regulations Title 29, Part 1910, Section 1910.1001 (33).

2.3 Canada

After the use of sprayed asbestos fireproofing was prohibited in the United States, manufacturers in Canada soon followed suit and voluntarily removed asbestos from their products (21). By 1974 no sprayed asbestos products were being applied in Canada. The manufacture of asbestos-containing pipe and boiler insulation block also ceased in Canada in 1973 (22), although existing stock was used until several years later.

It appears, based on this chronology, that health officials and legislators in Canada have been slower than their UK and US counterparts to obtain and respond to the information on friable asbestos. This is also true of the general public. According to Doern (2), the first Canadian press coverage of asbestos in buildings occurred in December 1978 in Winnipeg. The first articles on the subject regarding Ontario buildings appeared on July 31, 1979. The slow recognition of the possible hazard is also clear among workers in the asbestos industries. Although the asbestos hazard is well known to union officials as evidenced by the submissions made to the Royal Commission on Asbestos, this knowledge is not widely recognized by many workmen. In spite of the current publicity regarding the hazards of exposure to asbestos, the author has recently (November 1981) discussed safety precautions around asbestos insulation removal with both union and non-union employees performing this removal work. A majority of the men who had not worked on other supervised removal jobs professed to be unaware of the risks involved with the improper work practices being used. Also, in spite of the legal requirements imposed on employers in Ontario as a result of The Occupational Health and Safety Act (23), numerous jobs which should have been performed utilizing asbestos control precautions

according to the Ministry of Labour guidelines (24) were not. This often occurs as a result of ignorance of the hazard. However, a number of cases are known to the author where potential exposures to asbestos have been ignored due to the cost of correct asbestos abatement work. The enforcement of the recently published guidelines issued by the Ministry of Labour (24), particularly the section under "Demolition of structures containing asbestos" should prevent these improper procedures. These two sections read:

1. Prior to the demolition, partial demolition or renovation of a building or similar structure, all friable asbestos material shall be removed using the procedures referred to under 'Asbestos removal.'
2. Friable fibrous material present in buildings or similar structures must not be assumed to be asbestos-free unless records or analysis have confirmed it to be so.

Although these guidelines are very brief, they may be sufficient to alert the building owner or contractor to the need for full precautions. In this sense the enforcement of the rules above will fulfill the same function as the British (8) or American (14) regulations.

There is no legislated requirement for a universal programme of identification and control in Ontario although the Ministry of Education initiated a complete programme in 1979 which will be discussed in the next section. A number of government agencies and private companies have undertaken a process of identification of all friable asbestos in their buildings and control of any possible hazard of airborne asbestos. Some of the programmes underway in Ontario will be discussed in the following section to illustrate some methods by which the general public concern is being acted upon in Ontario.

3. CURRENT PROGRAMMES IN ONTARIO

Most of the programmes of inspection and control have occurred in the public sector. Although a small number of private firms have

instituted similar programmes they have generally not wished to provide their data as the programmes are not yet complete. Information on the various programmes is provided in the following sections. A number of the organizations have wished to remain anonymous and these are identified only by a general description of the type of organization and geographical location.

3.1 Ministry of Education

In July of 1979, the Ministries of Education and Colleges and Universities issued several memoranda (25, 26) requesting school boards, colleges, and universities to undertake a survey to identify all exposed asbestos-containing materials in their buildings. These were followed by a third memorandum instructing the boards to sample sprayed fibrous material and send it for analysis to the Ontario Ministry of Labour (27). This was accompanied by a manual, "Inspection of Buildings for Asbestos" (28). This manual, included here as Appendix I, provided information on sampling and analysis, corrective actions, and temporary control measures. The inspection programme covered all public and separate schools, colleges and universities in the province.

There has been no uniform pattern of conducting this programme of inspection. Some boards have hired outside consultants as inspectors whereas others have performed inspections using their own personnel. Usually a consultant is hired after the preliminary inspection has been performed and prior to any final decision being made regarding remedial work. The data presented in Table I (29) indicate that the inspections have been completed as of January 16, 1982. Some additional asbestos-containing material will continue to be found but these figures are essentially correct and complete.

The results confirm an expected trend that the school boards with larger schools, such as those in the central region, tend to have the highest percentage of schools with exposed or hidden sprayed asbestos. The category "Other Friable Asbestos" in Table I refers to such friable products as damaged acoustic tile, pipe insulation, or asbestos cement board, friable fire curtains, or damaged welding booths. These installations

TABLE I

SUMMARY OF ASBESTOS SURVEY IN ONTARIO SCHOOLS, COLLEGES AND UNIVERSITIES (AS OF JANUARY 26, 1982, TOTAL NUMBER OF SCHOOLS 4,727 BASED ON 79/80 DIRECTORY)

		NUMBER OF SCHOOLS REPORTING			
REGIONS	NUMBER OF BOARDS AND PROVINCIAL SCHOOLS	NO ASBESTOS	EXPOSED SPRAYED ASBESTOS	SPRAYED ASBESTOS IN AIR PLENUM	OTHER FRIABLE ASBESTOS
Central	47	2026	292	15	323
Eastern	18	585	31	1	23
Midnorthern	26	264	22	-	3
Northeastern	28	207	4	-	27
Northwestern	35	172	20	-	9
Western	21	671	58	3	48
Provincial Schools	23	16	3	-	4
TOTAL	198	3841 (81.26%)	430 (9.1%)	19 (0.4%)	437 (9.24%)
Colleges	22	8 (36.3 %)	8 (36.3%)	-	6 (27.4 %)
Universities	21	14 (66.7 %)	7 (33.3%)	-	-
GRAND TOTAL	241	3863 (80.99%)	445 (9.33%)	19 (0.4%)	443 (9.29%)

can usually be repairs or replaced at relatively low cost.

A considerable amount of work has been performed to rectify any potential problem up to this date. A summary of the provincial financial support for the work completed to date or planned in the school system (expressed in current dollars) is as follows:

Year	Number of Projects	Total Project Costs Approved By Ministry of Education
1980	541	$ 8,335,177
1981	127	4,768,467
1982	-	8,000,000 (Projected)
1983	-	8,000,000 (Projected)

The full cost of these projects would be greater than this because the province pays for only a fraction of the cost of any capital project of any school board. A large part of this expenditure has occurred in the 484 elementary, 106 secondary, and 13 special schools of the Metropolitan Toronto Board. These are as follows:

Year	Number of Projects	Total Project Costs Approved by Ministry of Education
1980	43	$ 3,152,974
1981	8	2,441,743

These figures again reflect the high unit cost for remedial work in the larger schools of Metropolitan Toronto.

At the present time no estimates exist for work beyond 1983. It is anticipated that some additional installations of asbestos-containing material will be identified and that more work will be performed in the future (30). The percentage of schools which report exposed sprayed asbestos (9.1%), sprayed asbestos in air plenums (0.4%), or other friable asbestos materials (9.2%) is significantly higher than the figures obtained for the U.S. E.P.A. (48) in which only 9.3% of all schools were estimated to have a potential exposure problem due to the presence of friable asbestos. This may be a genuine geographic difference or may imply that many of the installations enumerated by the Ministry of Education would not pose a potential exposure problem according to the criteria used by the EPA.

In compiling this information and deciding on appropriate corrective action, many school boards used information and advice from the Ministry of Education (30). The information included publications from the E.P.A. and the Metropolitan Toronto School Board (34). The general advice on asbestos-containing materials is summarized below. It must be stressed that the installations were individually evaluated.

Type of Material	Action
Sprayed Fireproofing in poor condition, exposed or above suspended ceiling	Remove
Sprayed Fireproofing in good condition, above suspended ceiling	Encapsulate
Sprayed Acoustic Plaster, poor condition within reach of occupants	Enclose
Sprayed Acoustic Plaster, poor condition outside reach of occupants	Encapsulate
Sprayed Acoustic Plaster, good condition	Leave as is
Pipe or Thermal Insulation, very badly damaged	Remove and replace
Pipe or Thermal Insulation, some damage	Repair
Pipe or Thermal Insulation, no damage	Leave as is
Acoustic Tile	Leave or replace as damaged

The various actions recommended will be discussed in later sections. The programmes of a number of boards or colleges will also be discussed in following sections.

3.1.1 City of Toronto Board of Education

The Toronto Board of Education has within its jurisdiction 119 public schools and 39 secondary schools which have a combined floor area of 13.7 million square feet (31). The schools tend to be older than the average age of schools in the province due to the demographic patterns. All of the schools have been inspected in several stages (32). The initial examination of buildings by visual inspection and by examining records such as year of construction and building plans was performed by

staff of the Toronto Board. This allowed an estimate of the extent and cost of this work to be prepared. At this time an outside consultant (45) was employed to perform bulk sampling and to mark the presence of sprayed asbestos on building blueprints ready for contract tendering. The analysis of the bulk samples was provided free of charge by the Ontario Ministry of Labour. The original estimate of buildings containing sprayed asbestos-containing material amounted to 50 buildings with a total estimated cost of abatement work of $17.2 million. Since all work could not be budgeted or controlled simultaneously, a mathematical algorithm was used to rate each installation. The algorithm was similar to the Ferris Index (35). High priority was generally assigned to installations with amosite, where other renovations were required, or where material was exposed, in an air plenum or in a fan room. The cost of abatement work performed in 1980 on six schools was $489,543.00 (1980 dollars) and on nine schools in 1981 was approximately $1.9 million. In all but exceptional circumstances, the sprayed materials were removed, thereby eliminating any future problem. A further 18 buildings are currently being tendered at an estimated cost of $3.7 million dollars. In many cases only certain portions of buildings have been done so that more than 20 buildings will still contain sprayed asbestos at the end of 1982. The cost of the asbestos removal has generally been substantially less than the original estimate which totalled $17.2 million.

A further 4 schools have also been identified as containing fire flaps or dampers with asbestos coatings. Due to public concern, these have been replaced with non-asbestos dampers, although some preliminary tests have indicated that measurable fibre levels are not generated from these asbestos-containing flaps (28a).

3.1.2 A Suburban Toronto Board

This board, which owns schools much newer than those of the Toronto Board of Education, has also carried out a large percentage of its asbestos abatement programme. The board has in its jurisdiction 130 public schools, 25 secondary schools, and 7 support buildings or other facilities. Immediately after the original request from the Ministry of Education (25) an initial inspection was performed by the caretaking staff of

each school. This survey served to identify the most obvious, exposed uses of the asbestos-containing materials but did not detect or report a large number of the less accessible installations. This survey was followed by a more detailed inspection by a single board employee. This inspection took in excess of 100 hours in the buildings of the board not including the time required to collate data from the bulk sampling. An outside consultant was then hired to re-inspect each of the schools with a possible problem, to mark the extent of the asbestos containing material on building drawings ready for tendering, and to give an evaluation of the relative priority of work. At the present time, inspections for fire stop flaps or fire stop dampers are being performed in every school.

The survey gave the following results:

Sprayed Fireproofing (Public Schools)	15
Sprayed Acoustic (Public Schools)	8
Sprayed Fireproofing (Secondary Schools)	16
Sprayed Acoustic (Secondary Schools)	1

Therefore, sprayed asbestos-containing fireproofing exists in 19.1% of all buildings and sprayed asbestos-containing acoustic material in a further 5.6%. The board initially used encapsulation to temporarily control some very exposed installations of fireproofing, but plans in the long-term to remove all sprayed asbestos-containing fireproofing where possible and to enclose or encapsulate where this is not possible. The acoustic sprays will be left untouched if they are in good condition or encapsulated if they appear to be degrading.

In 1980, a total of $550,000 was spent in the elementary system and $880,000 in the secondary system. Expressed in 1981 dollars it is estimated that a further $2.225 million will be needed in the elementary system and $4.1 million in the secondary system to complete all work with sprayed asbestos-containing materials. This work will be completed by 1986 at the current rate of progress.

3.1.3 Dufferin-Peel Separate School Board

This is a smaller board than the previously discussed boards (36). The board owns 63 school buildings of which 6 are considered senior elementary schools and the rest are elementary schools. Most of their buildings are of recent construction with about 30,000 sq. ft. of floor space with a small number around 60,000 sq. ft. At the time of the first Ministry directives, encouraged by parent pressure, the board hired the consulting engineering firm that had been employed for the construction of most of the buildings to handle the asbestos survey. The firm, through examination of plans and on-site inspection, determined that no sprayed material existed in any schools. It did identify 4 boiler rooms which contained asbestos block insulation and 27 schools with asbestos fire flaps or dampers. The entire cost of the inspection was approximately $13,000.00. Due to the poor condition of the insulation in the boiler rooms, a contract for $3,500.00 was awarded to re-canvas and re-paint the asbestos material in all four rooms.

Although some doubt exists as to whether the asbestos fire dampers or flaps do indeed pose a risk of releasing fibres (28a), the concern at the time led the board to award a contract for the encapsulation of all asbestos flaps and dampers. In the 27 schools a total of 765 units were removed, encapsulated with an asbestos sealer and replaced at a total cost of $109,000. Therefore, all possible asbestos-related problems in this board have been corrected.

3.1.4 A Rural Ontario Board

This rural Ontario Board responded in a fashion somewhat similar to the Dufferin-Peel Separate School Board. At the time of the original requests from the Ministry of Education, a brief survey of the 27 elementary, 5 secondary or vocational schools,and the board office was performed by employees of the board. This inspection revealed no friable asbestos and this was communicated to the Ministry. In the summer of 1980 this conclusion was questioned and the architectural firm which had been involved in much of the board's design and construction was hired to perform a re-inspection. All buildings were inspected by two members of this firm and samples were analyzed by the Ontario Ministry of Labour. The results of this inspection for friable asbestos-containing

products in elementary schools showed the following:

10 schools	None
5 schools	Acoustic tile
3 schools	Sprayed material and pipe insulation
3 schools	Pipe insulation
2 schools	Sprayed material, pipe insulation, and acoustic tile
2 schools	Pipe insulation and accoustic tile
1 school	Sprayed material
1 school	Sprayed material and accoustic tile

In the secondary schools,the following friable asbestos-containing products were identified:

2 schools	None
1 school	Sprayed material
1 school	Sprayed material and acoustic tile
1 school	Sprayed material, acoustic tile,and pipe insulation

There are two reasons for the difference between the first and second inspections. In the initial inspection, neither pipe insulation nor acoustic tile were considered friable. Also, the sprayed material is largely for acoustic purposes. Since it has generally been painted it was not readily identified as a friable asbestos-containing material. There is some disagreement currently between the Ministry of Education and this school board whether acoustic tile is friable and whether any control action is necessary for the tile. Further research may be necessary on this subject.

This board has completed the majority of the remedial work recommended by the architect. The expenditures to date or currently approved (in current dollars) are:

1980	\$100,000
1981	\$232,000
1982	\$ 85,000

There will be an estimated \$110,000 worth of work remaining at the end of 1982. The board has largely chosen to encapsulate the sprayed material and to remove and replace friable pipe insulation and acoustic tile.

3.1.5 Ottawa Board of Education

The Ottawa Board of Education programme has been very similar to that of the rural board discussed in the previous section. As early as 1979, all exposed sprayed asbestos had been removed from the Board's schools due to an alert from the Ottawa-Carleton Board of Health (37). The inspection of the 86 board buildings at the request of the Ministry of Education in 1979 and 1980 therefore showed only two with sprayed fireproofing behind a suspended ceiling. However, an additional 26 schools were found to contain sprayed asbestos-containing acoustical plaster. There were also an additional 6 schools with asbestos covered fire flaps and most schools had asbestos-containing pipe and boiler insulation. This was not felt to be a significant problem as the sealed jackets had been well maintained.

The total area of sprayed material in the 28 schools was approximately 40,000 square metres. It was decided that all the installations were suitable for encapsulation and this was performed in July and August 1980. The fire flaps were larely sealed with an encapsulant as well, although some damaged flaps were replaced. The board performed all this work for $91,000 including the job inspection and monitoring. This was a very low cost per unit area due to the method used by the board to tender the work and the desire of many contractors to begin working in asbestos abatement. The contractors therefore accepted a very low profit margin. The costs of this work will be considered in more detail in Chapter 5.

3.1.6 A Community College

The programme of the Ministry of Education also extended to the community colleges and universities in the province. The data provided in Table I from colleges and universities counts all the buildings at any one institution as a single building (i.e., if only one building out of twenty at a particular college has exposed sprayed asbestos, then this is counted as a positive response for the entire institution). The results from one College of Applied Arts and Technology will be discussed in this section.

The particular community college is located outside the major population centres of the Toronto-Hamilton area. The college is

quite young (being founded in the mid-1960's) and occupies buildings mainly constructed from 1965 to 1971 as well as several older buildings transferred to the college from other learning institutions. The programme of inspection was started as a result of the Ministry of Education memoranda (25, 26, 27). The initial inspection was performed by the Head of the Physical Plant and took a maximum of 5 days. This inspection encompassed all 16 of the buildings which have a combined floor area of nearly 65,000 square metres. The time per square metre required for this initial inspection was quite low because the buildings tend to be large and relatively new. Both of these factors decrease the time for inspection. Only one building of approximately 12,000 square metres was identified to contain friable sprayed asbestos. An independent consultant was then hired to perform a detailed inspection of this building and to prepare plans for the abatement work. The sprayed asbestos fireproofing had been applied on column headers and structural steel with some overspray on the concrete deck. There is a suspended ceiling and the ceiling space is used as a return air plenum. A decision was made, with advice from the consultant and the Ministry of Education, that the potential for exposure and economics of controlling the exposure are such that the fireproofing should be removed and replaced with an asbestos-free substitute.

This work, which will cost an estimated $750,000 (in 1981 dollars), is planned to be phased over four years starting in 1983. Until the material is removed, air monitoring is being performed on a continuing basis to ensure that no major change has occurred in the condition of the installation.

3.1.7 University of Toronto

The asbestos control programme of the University of Toronto is also in progress due in part to the Ministry of Education memoranda (25, 26, 27). The University of Toronto is by far the largest of the Ontario universities but the status of the work is typical of most Ontario universities (30). The University of Toronto owns a total of 126 buildings. Most of these are large academic, office, residential, or industrial type buildings located on the downtown Toronto campus of the university (49).

The inspections have been carried out by building managers or building engineers. Of the 126 buildings at the downtown campus asbestos — containing sprayed material has been identified in 9 buildings. This material is largely applied as fireproofing on structural steel or steel decks, although some also serves as an acoustic treatment. A much larger number of buildings, of the order of 100, contain non-sprayed asbestos in the form of ceiling tiles, boiler and pipe insulation. Air monitoring has been performed in most of the buildings containing sprayed asbestos-containing material by the Occupational Health and Safety Inspectors of the Ontario Ministry of Labour. None of the results have indicated any cause for concern to the Ministry. The University, through the Occupational Health and Safety Committee, is continuing work in establishing priorities for work and ensuring that no work is undertaken which would worsen any potential exposure situation.

The restrictions on capital expenditures over the last few years have reduced the amout of money available for performing any asbestos control work. In any instance where renovations are scheduled which will disturb the sprayed asbestos-containing materials the guidelines of the Ontario Ministry of Labour are followed (24). These require the complete removal of the asbestos-containing material before the renovations are performed.

No accurate estimate of the total area or total cost of a complete asbestos abatement programme has been made. The three major projects in the largest building have been estimated to cost in excess of $5,000,000.00 (expressed in 1981 dollars). Until the funds become available or a clear exposure problem is shown, this work will likely remain in abeyance.

3.2 Government of Canada

3.2.1 Public Works Canada

The programme of inspection and control of Public Works Canada (PWC) was started in mid-1980 (38). Since PWC has under its ownership and management approximately 12,950 buildings across Canada, it was felt necessary to have regional managers and staff acquainted with asbestos sampling and control procedures. The buildings fall into the following categories: administrative (450), operational (9500), institutional (100), and residential (2900). These categories include office buildings, public buildings, industrial and laboratory buildings, training centres, mail processing buildings, heating plants, and garages.

A group of regional employees attended a specialized course presented by the Ontario Research Foundation and on return to their regions, carried out the initial inspection and sampling program. The inspection was limited to sprayed materials since pipe and boiler insulation were to be controlled by the operation and maintenance section. A total of 3,730 buildings (of the 12,950 total) were judged to require physical inspection based on a review of building plans, years of construction, and a knowledge of the building types (i.e., residential eliminated).

The initial inspection identified only 34 buildings with sprayed asbestos containing materials. The estimated cost to correct these installations (largely through removal) was $30.4 million expressed in 1981 dollars. It is anticipated that this cost may be reduced as contractors become more familiar with asbestos work.

At approximately this time, the Treasury Board established a committee called the Treasury Board Advisory Committee on Asbestos Control (TBAC/AC) (39). The Committee consisted of representatives of the Treasury Board, Public Works, Health and Welfare, Transport, Labour, and National Defence. The purpose of this committee was to:

(a) advise the Treasury Board on all matters relative to asbestos in buildings;

(b) co-ordinate assessment of any necessary control actions and co-ordinate programmes of various departments;

(c) monitor implementation of control programmes;

(d) provide information and advice to departments to assist them in their communications with employees.

All 34 buildings shown to contain friable sprayed asbestos by PWC inspection were then re-inspected by the assessment team of the Treasury Board Advisory Committee on Asbestos Control (TBAC/AC) to provide a uniform basis of judgement. Of the 34 buildings the following actions are planned:

Removal	22
Encapsulation	1
Enclosure	3
Management and Surveillance	8

Of the approximately 1000 buildings in Ontario (including Ottawa in the National Capital Region in this total), 23 contain sprayed friable asbestos-containing material. Of these buildings only 2 are subject to management and surveillance. Work on 11 of the remaining 21 has been completed as of February 1982. The planned abatement work will be completed by 1986 under the current plan and rate of expenditure. The work completed to date has generally been performed with a minimum of disruption by transferring employees elsewhere in the building. This avoided the need for leasing alternate space. Expressed as a percentage of the buildings physically inspected approximately 2.3% of the buildings in Ontario and 0.9% of the buildings in Canada as a whole contain sprayed friable asbestos. This reflects the greater likelihood of sprayed material in the larger buildings in the urban areas of Ontario.

In addition to these buildings, PWC leases, on behalf of other government departments, approximately 2,250 buildings (1320 administrative or office buildings, 900 operational (heating plants, post offices, etc), and 30 institutional), of which approximately 450 are in Ontario. Of these buildings in Canada 28 contain sprayed friable asbestos and of these 28, all but 3 will require some remedial work other than management and surveillance. Of these 28 buildings, 20 of them are locat in Ontario. To date no contract measures have been undertaken in any other these leased buildings. Expressed as a percentage again, 4.4% of the Ontario buildings and 1.2% of the Canadian total contain sprayed friable asbestos.

.2.2 National Capital Commission

The National Capital Commission manages a large number of generally older buildings in the Ottawa - Hull area (40). There are approximately 250 commercial properties among them, mainly retail stores, restaurants, or service establishments. Since friable asbestos products are not commonly used in residential buildings only these commercial properties and several institutional buildings were inspected. Two employees of the National Capital Commission were trained in asbestos inspection and control and conducted the inspections. The inspections required approximately 100 to 120 man days since the buildings tended to be old and to have undergone extensive alterations which complicates the inspection.

Only two buildings were found to contain sprayed asbestos. In each of these the material was applied as fireproofing and thermal insulation in service and boiler rooms. The total area was approximately 300 square metres. In addition exposed friable asbestos was found in damaged pipe, furnace and boiler insulation in more than 50 buildings.

The sprayed material was removed in 1981 at a total cost of approximately $35,000. The damaged thermal insulation was repaired by Commission employees or with local contractors by covering the friable material with paint or clay impregnated cloth.

3.2.3 Other Government Departments

Although they will not be discussed in detail, all other federal departments have completed inspection programmes and are in the process of performing any necessary remedial work. These departments include Transport Canada, National Defence, Indian and Northern Affairs, Correctional Services, and Parks Canada.

3.3 Ontario Ministry of Government Services

The Ontario Ministry of Government Services (MGS) is reponsible for the operation of approximately 8,000 buildings owned by the province and another 1,300 buildings wholly or partly leased for various ministries. The programme established by this Ministry is very different from the programmes described earlier (41). MGS has not initiated a general programme of inspection and sampling but instead responds to any specific enquiry or employee concern. In any routine enquiry the trained inspectors of MGS will visit the site,

visually inspect the installation, take bulk samples, and, if it is felt necessary, air samples. All samples (both bulk and air) are then analyzed by the Ministry of Labour laboratories. If any emergency situation arises, Ministry of Labour inspectors can be called upon to provide site inspection and sampling. MGS relies on the Ministry of Labour for advice as to appropriate action since this Ministry is considered to have final jurisdiction (41).

As of March 12, 1982, 68 buildings have been sampled for asbestos. They fall into the following categories:

Schools	20
Correctional Institutions	10
Warehouses	3
Public Entertainment Facilities (auditoriums)	1
Institutional Buildings (courthouses)	7
Offices	27
Total:	68

Of the 68 buildings inspected, exposed friable asbestos products were identified in 37 as follows:

Schools	7
Correctional institutions	6
Warehouses	2
Pyblic Entertainment Facilities (auditoriums)	1
Institutional Buildings (courthouses)	6
Offices	15
Total:	37

No exposed asbestos was identified in the following buildings:

Schools	3
Correctional Institutions	1
Warehouse	1
Institutional	1
Office	7
Total:	12

The remainder of the buildings (19 in total; 10 schools, 3 correctional institutions, 5 offices, and one institutional building) are still under investigation and analysis.

Air sampling has been conducted in 13 of the 37 buildings identified as containing exposed asbestos. To date none of the completed bulk analyses or air sampling tests have led the Ministry of Labour to recommend any major asbestos abatement work. MGS has adopted guidelines for its maintenance employees to protect the workers and other building occupants from exposure to asbestos (42). These guidelines (attached as Appendix J) cover work above suspended ceilings, on pipe insulation, or any inspection, maintenance, repair, construction, or demolition work where asbestos fibres may be liberated. Recommendations are also made regarding personal protective equipment, housekeeping, ventilation, and disposal.

In addition to the sprayed asbestos a very large amount of exposed asbestos-containing friable pipe insulation has been identified. This problem has been remedied by simply repairing and recovering the insulation following the techniques outlined in MGS guidelines.

This programme of the provincial government has apparently been carried out at low cost. Several MGS employees have attended on a course on asbestos identification and control but again the Ministry of Labour is relied on for advice as to the appropriate corrective procedures. These measures have been judged to be appropriate by MGS and the Ministry of Labour at the deputy minister level (41). There is also agreement that if any major repair, renovation or demolition is planned in contact with friable asbestos-containing materials that the more recent guidelines (24) of the Ministry of Labour will be followed.

3.4 City of Windsor Utilities Commission

The concern over asbestos has extended beyond the federal and provincial governments. A number of municipal commissions or utilities have also initiated programmes of inspection and control. The City of Windsor Utilities Commission initiated a programme of inspection in the summer of 1981 using an outside consultant (43, 44). A total of 27 buildings (some consisting of several subdivisions for a total of 46 separate areas) were inspected. These buildings were constructed over a long period (from 1910 to 1975) and were water filtration

and pumping stations, electric stations,and office areas. The consultant detected no sprayed asbestos whatsoever and concluded that in approximately 33 areas no action was needed since either no asbestos at all was detected or no potential hazard existed from the type of asbestos-containing insulation detected. These non-hazardous materials included circuit breakers, circuit flash shrouds,and transite panels.

Friable asbestos-containing materials were detected in the remaining 13 areas. This was largely in the form of corrugated pipe wrapping or thermal block insulation on boilers or pipes. A number of these were easily repaired by board employees. A contract was let to a contractor for 7 remaining areas. The contract generally called for removal and replacement of the asbestos containing insulation. The total contractor cost for this work was in the region of $24,000 and should be complete at publication of this study.

3.5 Private Sector

The private sector has generally been much slower to respond to public and employee concern over the issue of asbestos in buildings. This is not unexpected since no legislation has been enacted requiring asbestos control programmes and the cost of such programmes is substantial. Until some specific action is legislated or enforced a widespread asbestos control programme will not likely occur in the private sector. The control program in the schools has preceded legislation largely due to the emotional issue of parental concern over exposure of children. This was coupled with the lower level of public concern for spending public money than a private concern for spending its own funds.

In spite of this a significant number of private organizations have undertaken asbestos removal or encapsulation contracts and others have established management and control programmes. These programmes have generally occured due to employee concern, action by the Ministry of Labour,or when renovations or demolitions have been undertaken. The author is personally aware of these programmes in retail stores and malls, office and commercial buildings, industrial or manufacturing plants, mining operations, banking institutions, private utilities,and service industries. It is not possible to discuss these programmes in detail since most firms in the private sector do not wish to publicize their asbestos abatement programmes outside their own staff or buildings.

4. Options in Inspection

The response to the public concern over asbestos in buildings in Ontario has resulted in the inspection and control programmes described in this chapter. These programmes can be grouped into two general types. The Ministry of Education, Federal Government, and Windsor Utilities Commission programmes are typical of one type of inspection programme. They are similar to the programmes of the U.S. Department of Education (18), the Alberta Government (46), and some other jurisdictions. This approach calls for all buildings to be inspected by reference to building plans and physical inspection and all friable asbestos to be identified and evaluated. The appropriate control procedure is then selected based largely on a visual inspection. These programmes are expensive due to the extensive inspection programmes, but will certainly identify any potentially hazardous installations.

The second type of programme is typified by the Ministry of Government Services and most programmes in the private sector known to the author. In this approach no universal inspection programme is established but concerns expressed over individual buildings are dealt with as they arise. Once the concern is expressed, either a visual inspection or air monitoring is used to determine the potential exposure problem. The private sector generally uses a visual inspection, while the Ministry of Government Services uses air monitoring performed by the Ministry of Labour. This second type of programme is less costly but may not identify all potential hazards of airborne asbestos (particularly hazards posed to maintenance personnel performing work in the area). These two approaches to an inspection programme will be considered in later chapters when additional information on airborne asbestos levels in buildings is presented.

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CHAPTER 3

INVENTORY OF BUILDINGS WITH POTENTIAL ASBESTOS EXPOSURE HAZARD

1. INTRODUCTION

No estimate of the extent of friable asbestos-containing materials in Ontario buildings has been developed at the present time. The establishment of an inventory of buildings with a potential asbestos exposure hazard would serve several purposes. It would provide a basis for estimating the possible expenditures necessary for both inspection and control. It could also be used as a basis to estimate the number of persons who are potentially at risk. If a detailed inventory was presented in a suitable fashion, it could also be used by Ministry of Labour inspectors as an aid in ensuring that correct procedures are followed during the renovation or demolition of buildings containing friable asbestos.

There are many obstacles to compiling such an inventory. In order to identify conclusively every potential "problem" building in the province, every building which might conceivably contain friable asbestos would have to be physically inspected. This would be a formidable task which would extend beyond the time scale of the Royal Commission on Asbestos. The cost of such a survey and the associated analysis of any suspect materials would be considerable. The cost of inspection is considered in more detail in Chapter 4. There are several alternatives to this universal inspection programme.

If a scientifically selected cross-section of Ontario buildings could be chosen from an inventory of all buildings in the province, then the task of compiling the inventory would be reduced in size. The U.S. EPA has used this route to estimate the extent of a potential asbestos exposure problem in the U.S. public school system (1). This research required approximately one year to complete.

Since an inventory of all buildings in Ontario does not exist, a second route was selected to establish a building inventory. This route involved the preparation of two estimates. Firstly the organizations currently performing programmes of inspection and control were asked to provide information on the extent of friable asbestos in their buildings. This figure was expressed as a fraction of their total buildings and, where possible, as a fraction of their total floor areas. Secondly, an estimate was prepared of the total number of buildings or total floor area of buildings which were constructed during the period when friable asbestos products were in use. Both of these estimates are expected to be very approximate. Multiplying the estimated percentage by the estimated total number of buildings constructed should give an order of magnitude estimate of the presence of friable asbestos in Ontario buildings.

The methods of compiling the Ontario inventory and the estimate of buildings with friable asbestos along with the limitations of the estimate will be presented in this chapter.

The EPA is currently conducting a second study to estimate the potential number of problem buildings in the private sector. This second EPA study, which will be completed in mid-1982, uses the same approach to compiling an inventory as the present Ontario study.

2. EXTENT OF PROBLEM IN INSPECTED BUILDINGS

2.1 Introduction

A number of programmes of inspection have been identified in Chapter 2. These programmes are largely in the public sector, mainly in schools. Some programmes exist in the private sector but as a general rule they are not as well advanced nor are they comprehensive. In addition many private building owners were reluctant to relrease their information. It is therefore not possible to use information from the private sector in preparing the building inventory. The data available must therefore be used with caution as the buildings on which it has been compiled are not representative of the private sector. The buildings of Public Works Canada

and the Windsor Utilities Commission are likely more typical of the universe of Ontario buildings. It was initially hoped that the information received from building owners could be used to determine the rate of occurrence of potential problems in buildings of various types. This proved to be impossible due to the limited types of buildings inspected and limited quantities of the information.

Another problem in compiling the inventory is that no general agreement exists between the organizations performing the inspection programmes as to what constitutes a "problem" building. In addition, some of the inspections included only sprayed asbestos-containing materials, not friable boiler or pipe insulation. Therefore, for the sake of the present work the inventory will primarily concentrate on sprayed asbestos-containing materials whether or not these sprayed materials in fact would be considered to pose a potential hazard at this time or not. Since the recently proposed Ontario Ministry of Labour Guidelines (6) specify that all friable asbestos-containing material must be removed before disturbance by renovation or demolition, then it is reasonable to include all friable sprayed asbestos-containing material in the inventory. It would be much more difficult to establish an inventory of buildings with friable asbestos-containing pipe and boiler insulation since the use of these materials is much more widespread and it has not been included in many inspection programmes. In addition, such insulation is often found only in a few service areas or on a few feet of piping and it is difficult to estimate this use. In the few cases where information is available on this asbestos-containing insulation, it will be presented as well.

2.2 Results of Selected Programmes of Inspection

The results of a number of programmes of inspection are summarized in Table I. The majority of these have been discussed in Chapter 2. However, the information provided by several sources discussed in Chapter 2 was not useful in preparing an inventory, and has been excluded from the Table. The information from Alberta Government Services (4) and the U.S. Environmental Protection Agency regarding elementary and secondary schools (1) have been added to this list.

TABLE I

SUMMARY OF RESULTS OF PROGRAMMES OF INSPECTION

Organization	Type of Building	Number of Buildings Inspected	Percentage with Sprayed Asbestos	Percentage with Other Friable Asbestos	Total Area Inspected 1000 m^2	Percentage of Area with Sprayed Asbestos
Ministry of Education	Elementary & Secondary Schools	3,841	9.5	9.2	(a)	(a)
Toronto Board of Education	Elementary & Secondary Schools	158	31.6	10.7(b)	1,275.0	14.7
A Surburban Toronto Board	Elementary & Secondary Schools	162	24.7	(a)	(a)	(a)
Dufferin Peel R.C.S.S.	Elementary & Senior Elementary	63	0.0	49.2(c)	(a)	0.0
A Rural Board	Elementary & Secondary	33	30.3	21.2(d)	143.6	8.6
Community College	College Buildings	16	6.3	(a)	65.0	18.4
University of Toronto	University Buildings	126	7.1	72.2(e)	(a)	(a)
Public Works Canada	Administrative & Operational; Canada-wide	10,500	0.34	(a)	(a)	(a)
Public Works Canada	Same as above; Ontario only	2,700(f)	0.85(f)	(a)	(a)	(a)

TABLE I (continued)

Organization	Type of Building	Number of Buildings Inspected	Percentage with Sprayed Asbestos	Percentage with Other Friable Asbestos	Total Area Inspected 1000 m^2	Percentage of Area with Sprayed Asbestos
Public Works Canada	Leased Office and Operational; Canada-wide	2,250	1.2	(a)	(a)	(a)
Public Works Canada	Same as above; Ontario only	450	4.4	(a)	(a)	(a)
National Capital Commission	Retail and Commercial	250	0.8	20.0%	(a)	(a)
Windsor Utilities Commission	Utility and Service Buildings	46	0.0	28.2%	23.3	0.0
Alberta Government Services	Government Buildings	(a)	(a)	(a)	(a)	2.0
U.S. EPA	Elementary & Secondary Schools	(a)	9.3(g)	(a)	(a)	(a)

(a) not reported
(b) fire stop flaps only; no sprayed asbestos in these buildings; pipe insulation not reported
(c) largely fire stop flaps; some pipe insulation
(d) accoustic tile or pipe insulation, no sprayed asbestos in these buildings
(e) pipe insulation and ceiling tiles
(f) approximation only
(g) buildings with potential exposure problems

The results listed in Table I illustrate the problems in using data from a sample of buildings which are not scientifically selected to represent all the buildings in the province. The percentage of buildings with a sprayed material ranges from 0.0 to 31.6%. The percentage of buildings with non-sprayed friable asbestos ranges from 9.24% to 72.2%. Therefore, without knowing the number of buildings in each category in the province it would be very difficult to arrive at a close estimate of the number of buildings with a potential exposure problem It appears that the percentage of the total building area with sprayed asbestos is greater in the school system than in the other sectors listed in Table I. This appears to be confirmed by data collected by the U.S. EPA which shows 9.3% of all school buildings pose a potential hazard of airborne asbestos. Sprayed friable asbestos is more prevalent in certain types of buildings such as steel as opposed to concrete structures, multi-storey as opposed to lower structures. The surveys available were not sufficiently detailed to forecast accurately the use of sprayed asbestos.

As a general rule,where both the percentage of affected buildings and the percentage of the total building area is reported, the former figure is higher. This is due to the fact that often only a small part of a building is sprayed with an asbestos-containing material. Only the community college which had one very larged affected building was opposite to this pattern.

The non-school sector produced a considerably lower percentage of affected buildings. Public Works Canada (PWC) identified only 0.34% of its own buildings and 1.2% of its leased buildings with sprayed friable asbestos. The PWC calculation included all buildings under its jurisdiction. If one considers the Ontario Region only, 0.85% of the total buildings owned by PWC contain sprayed friable material. In the Ontario region 4.4% of all PWC leased buildings contain sprayed asbestos-containing material. The percentage is higher in the leased buildings since they tend to be larger and more likely to contain friable sprayed materials for fireproofing purposes due to the methods of construction.

The remaining non-school programmes have also shown significantly lower percentages of sprayed asbestos-containing material than in schools. The National Capital Commission (NCC) identified only 0.8% of its buildings with sprayed asbestos-containing material. The percentage of area affected (while not available) would be less than this figure since the affected areas are small service areas. Windsor Utilities Commission buildings contained no sprayed material. The percentage of buildings with other friable asbestos (mainly pipe insulation) is large in both NCC (20.0%) and Windsor Utilities Commission (28.2%). The Alberta Ministry of Government Services has recently completed a survey of all sprayed friable asbestos-containing material in its buildings. Approximately 2% of the total area of the buildings owned by the Alberta Government were shown to have sprayed asbestos-containing material.

If one considers the very limited data available and recognizes that it may not be representative of all buildings in Ontario, due to the largely governmental and school buildings inspected, the preparation of an accurate estimate of the percentage of affected buildings or floor area is seen to be impossible. The programmes in the school systems have detected from 0.0 to 18.4% of the floor area with sprayed friable asbestos. In the non-school sector, the programmes have indicated from 0.0 to 4.4% of the inspected buildings contain sprayed friable asbestos. The range of these data indicates that the overall percentage of affected buildings or affected floor area will likely lie in the range from 1 to 10%. This will be considered in more detail in a later section. In order to produce a closer estimate than this, it would be necessary to perform a much more extensive programme of inspection. This was beyond the scope of the current work.

The use of sprayed asbestos was most widespread in the years 1950 to 1973. The information provided by the various sources did not usually specifically identify the ages of their buildings. It is likely however that most buildings constructed before 1950 were in some way renovated or added to in the years 1950 to 1973 when the province was experiencing a period of rapid growth and construction.

Where reported, it is clear that a higher percentage of buildings contain asbestos-containing pipe and boiler insulation, ceiling tile, or fire stop flaps than sprayed material. These percentages range from 10.7 to 72.2%. This material is usually confined to the service areas or ducts of the building and no estimate of the total area affected can be made. Information provided in other chapters indicates the substantial costs of removing this pipe and boiler insulation and the severe worker exposure that this removal may produce. In spite of these considerations, no attempt will be made to include the buildings containing friable asbestos pipe insulation in the building inventory as the available data are not sufficiently complete for this purpose.

3. BUILDINGS CONSTRUCTED 1950 - 1973 in Ontario

Sprayed asbestos-containing products have been in use in North America since 1935. Preliminary results from the EPA building inventory study (2) indicate that at least 90% of the usage of sprayed asbestos containing products occurred after 1950 when it was given Underwriters Laboratory approval as a fireproofing coating. Although no systematic study has been made in Canada it would be expected that a similar pattern of use occurred here. It would therefore be reasonable to assume that only buildings constructed or renovated in the years 1950 to 1973 are liable to contain sprayed asbestos-containing materials. The use of asbestos thermal pipe or boiler insulation dates from the 1920's or 1930's but as discussed earlier this material will not be considered in the building inventory.

Detailed data from which to compile an inventory of Ontario buildings constructed in this period are not readily available. The limited information that is available is from a variety of sources and is difficult to combine. The report of the City of Toronto's Department of Public Health (3) used the total number of building permits issued from 1945 to 1973 to estimate that approximately 163,347 buildings in the City of Toronto would require some form of inspection. This

total includes new construction and renovations of all types of structures. Most of these would not have any likelihood of containing sprayed asbestos since the total includes residential construction, temporary structures, fire escapes, etc. Few residential buildings contain sprayed asbestos. The construction techniques of single family residences or multi-storey apartments generally do not require any sprayed fireproofing or acoustic materials. A very limited amount of sprayed material has been used for thermal insulation in residences but this is unusual.

Statistics Canada provides data on the value of building permits issued from 1951 onwards (5). The data recorded for Ontario under the categories Industrial, Commercial, and Institutional and Governmental are shown in Table II. The presence of sprayed asbestos in residential accommodation is quite rare so this category is not considered. All data are reported in current dollars (no allowance for inflation). This listing will include renovations and new construction. The value of the construction may be underestimated since the cost of the permit is based on the estimated value of the construction and there is a tendency to underestimate the value. The same information is presented for the City of Toronto (1950 - 1973) in Table III. The information has been summarized in Table IV (a) and (b), for the years 1950 - 1959, 1960 - 1969, 1970 - 1973. Table IV (b) also contains the percentage of total construction in the province which occurred in the City of Toronto in each of the categories and year groupings.

Since these data report the dollar value of construction it is necessary to convert in some way to the total square metres of construction or number of buildings constructed. Information which would enable this to be done was available only from the City of Toronto which maintains a land use file from 1940 (7). This land use file records any changes in the land use caused by construction or demolition. The information is summarized in Table V for buildings built in the City of Toronto between 1950 - 1973. This information has been grouped into three sub-divisions:1950 - 1959, 1960 - 1969,and 1970 - 1973. This information does not include relatively minor renovations to buildings although major renovations would be included. The average area of the buildings in each category is shown as well. The average cost per building and average cost per square metre is calculated from the building permit values in Table IV (b) and the land use information and is reported in Table V.

TABLE II

Value of Industrial, Commercial, and Institutional and Governmental Building Permits Issued in Ontario 1951 - 1973 (reported in thousands of current dollars)

Year	Industrial	Commercial	Institutional & Governmental
1950*	81,545	72,772	61,468
1951	81,545	72,772	61,468
1952	69,594	82,605	61,250
1953	111,940	95,877	82,288
1954	93,388	86,902	100,767
1955	79,078	117,139	96,425
1956	100,998	120,350	127,691
1957	95,880	161,718	126,455
1958	90,143	155,205	203,333
1959	93,940	189,096	185,639
1960	107,446	173,002	186,840
1961	95,559	197,372	200,356
1962	108,872	177,245	303,557
1963	151,910	182,726	264,233
1964	182,511	240,319	304,259
1965	212,291	275,705	400,637
1966	281,534	330,478	452,803
1967	200,868	280,858	518,698
1968	183,292	294,133	552,001
1969	299,300	382,728	512,823
1970	230,560	414,513	578,223
1971	196,882	488,607	459,263
1972	278,890	564,472	430,965
1973	428,004	849,323	377,689

* figure for 1950 not available; value for 1951 used for 1950.

TABLE III

Value of Industrial, Commercial, and Institutional and Governmental Building Permits Issued in the City of Toronto 1951 - 1973 (reported in thousands of current dollars)

Year	Industrial	Commercial	Institutional & Governmental
1950*	12,891	16,535	8,780
1951	12,891	16,535	8,780
1952	9,700	15,391	9,025
1953	21,386	35,021	7,153
1954	17,481	20,331	11,270
1955	5,805	25,647	8,793
1956	9,690	21,694	11,563
1957	7,444	61,005	21,262
1958	5,723	41,540	29,401
1959	7,124	52,413	21,567
1960	15,116	38,959	34,123
1961	9,665	56,144	24,394
1962	5,933	39,659	44,904
1963	15,994	43,544	28,218
1964	10,113	53,804	67,624
1965	4,391	87,672	48,698
1966	8,941	97,959	29,060
1967	8,092	76,754	88,086
1968	12,865	73,490	70,446
1969	13,469	82,953	87,713
1970	26,834	141,221	68,961
1971	23,669	175,789	62,811
1972	4,730	114,728	76,320
1973	19,787	247,633	46,832

* figure for 1950 not available; value for 1951 used for 1950.

TABLE IV

Value of Industrial, Commercial, and Institutional and Governmental Building Permits Issued 1950 - 1959, 1960 - 1969, 1970 - 1973 (thousands of current dollars)

(a) Ontario

Years	Industrial	Commercial	Governmental and Institutional
1950 - 1959	898,051	1,154,436	1,106,794
1960 - 1969	1,823,583	2,534,566	3,696,207
1970 - 1973	1,134,336	2,316,915	1,846,140

(b) City of Toronto
(percentage of Ontario total given in brackets)

Years	Industrial	Commercial	Governmental and Institutional
1950 - 1959	110,135 (12.3)	306,112 (26.5)	137,594 (12.4)
1960 - 1969	104,579 (5.7)	650,938 (25.7)	523,266 (14.2)
1970 - 1973	75,020 (6.6)	679,371 (29.3)	254,924 (13.8)

TABLE V

Data on Land Use for the City of Toronto (1950-1973)

Years	Category	Number of Buildings	Floor Area m^2	Average Building Floor Area m^2	Average Building Cost Thousand $	Average Cost $ Per m^2
1950-1959	Industrial	419	646,977	1,544	263	170
	Commercial	2,166	2,203,969	1,048	146	139
	Governmental And Institutional	181	561,075	3,100	760	245
1960-1969	Industrial	165	174,432	1,057	634	600
	Commercial	1,446	2,762,112	1,910	450	236
	Governmental And Institutional	136	949,653	6,983	3,847	551
1970-1973	Industrial	20	36,220	1,811	3,751	2,071
	Commercial	290	1,143,433	3,943	2,353	594
	Governmental and Institutional	36	228,916	6,359	7,081	1,113

It is clear that the data from the two sources are not completely compatible and that this may introduce a considerable error in the cost per square metre or cost per building. This incompatibility is greatest in their treatment of renovations. The information from Statistics Canada includes all building permits but the information from the City of Toronto described new buildings or major renovations only.

The average cost per square metre and average cost per building in the City of Toronto have been used with the information in Table IV (a) to estimate the total number of buildings and total floor area of industrial, commercial, and governmental and institutional construction in Ontario. This information is presented in Table IV. The City of Toronto accounts for a significant percentage of the total construction in Ontario (approximately 8.0% of industrial, 27.0% of commercial, and 13.5% of governmental and institutional construction, 1950 - 1973). The City of Toronto is not typical of the province in the average cost of individual projects. The average cost per square metre of floor space is likely more typical, although probably still above the provincial average. In any case the calculated information in Table VI must be regarded only as a very general approximation.

4. ESTIMATION OF SPRAYED ASBESTOS IN ONTARIO BUILDINGS

Due to the very approximate estimate of the volume of construction and percentage of construction with sprayed asbestos products, the estimate of the extent of sprayed-asbestos containing materials in Ontario buildings will be subject to considerable uncertainty. It should be considered as an order of magnitude estimate which may be useful for discussion. As pointed out earlier the preparation of a more accurate estimate would require an extensive programme of inspection of a group of scientifically selected buildings representatives of all types of buildings in the province.

Some of the limitations of the data have been discussed in the previous sections. A major difficulty arises because the programmes of inspection have been performed in the public and school sector. These buildings are not representative of many types of construction in the private sector. Sprayed asbestos-containing materials have been used in industrial, mining, and heavy and light manufacturing buildings.

TABLE VI

Total Number of Buildings and Total Floor Area of Industrial, Commercial, and Governmental and Institutional Buildings in Ontario 1950 - 1973 (estimated from Tables IV and V)

Years	Category	Number of Buildings	Floor Area Thousand m^2
1950 - 1959	Industrial	3,414	5,282
	Commerical	7,907	8,305
	Governmental and Institutional	1,456	4,517
	TOTAL	12,777	18,104
1960 - 1969	Industrial	2,876	3,039
	Commercial	5,632	10,740
	Governmental and Institutional	960	6,708
	TOTAL	9,468	20,487
1970 - 1973	Industrial	302	547
	Commercial	984	3,900
	Governmental and Institutional	260	2,081
	TOTAL	1,546	6,528

No information was available from this sector and the extent of its use in this sector, while expected by the author to be substantial, is not known. The percentage of the total area or total building containing asbestos is also extremely variable. The percentage of areas containing sprayed asbestos-containing materials range from 0.0 to 18.4%. Only five of the inspection programmes contained sufficient information to express the extent of sprayed asbestos-containing material as a percentage of total floor area. Most of the programmes reported only the percentage of buildings with sprayed asbestos-containing materials. The percentage of area affected is usually much smaller than the percentage of buildings affected since often only a part of a building is treated with sprayed asbestos-containing material. The establishment of the inventory should be performed using the lower area percentage because the cost of remedial work is related to the area of the sprayed material not to the total building area.

Another major limitation of the data concerns the years over which the building data is available. The programmes of inspection reported in Table I were generally for all buildings owned or operated by the particular organization with no regard to the year of construction. At times more recently constructed buildings (post-1973 or 1975) have been excluded from the inspections. Most programmes of inspection are performed in this fashion since the exact year that older construction or renovation was performed is not known. The data on buildings constructed (or extensively renovated) in Ontario are complete and available only from 1950. Therefore buildings constructed prior to 1950 and not renovated between 1950 and 1973 are not included in the construction inventory in Table VI. Although the buildings constructed or extensively renovated from 1950 to 1973 form a substantial part of the total area of the type of buildings under consideration, exclusion of the pre-1950 construction is a serious deficiency in the total inventory. Without a more complete survey of a selected group of buildings there was no way to overcome this problem. Another problem concerns the minor renovations of buildings. Since the data from the City of Toronto did not include minor renovations, these buildings would also be excluded from the inventory of buildings listed in Table VI. Since at least some of the sprayed asbestos-

containing material was applied as part of minor renovations, this tends to exclude another segment of possibly affected buildings.

One of the most serious deficiencies of the data involves using information on the industrial, commercial, institutional, and governmental buildings in the City of Toronto to extrapolate to the province as a whole. The projects in the City of Toronto (with the possible exception of industrial construction) will certainly be larger than the provincial average. The calculated number of buildings constructed in the province between 1950 and 1973 (23,791 from Table VI) will therefore be an underestimate. The average cost per square metre of construction in the City of Toronto would also be expected to be higher than the provincial average which would also produce an underestimate of the total floor area of construction in the province. Finally, the value of construction is based on building permits which themselves tend to be underestimates of the cost of construction (8). This last factor may not be a problem as the information for the province and for the City of Toronto would both be subject to the same underestimate. These would therefore tend to cancel each other.

Subject to the limitations discussed above and based on the data in Table I and discussions with the various organizations involved, it is the author's conclusion that a minimum of 2% and a maximum of 10% of the total area of industrial, commercial, institutional, and governmental construction in Ontario will contain sprayed asbestos-containing material. The percentage of affected area reported for the Toronto Board of Education and the Community College exceed 10% and the percentage for the Dufferin-Peel R.C.S.S. and Windsor Utilities Commission are less than 2%. This is due to the specific types of construction used in these organizations. Due to the large number of buildings in the school system and some specific construction projects of large area in the private sector the overall affected area will likely exceed this 2% figure. The most probable percentage of area with sprayed asbestos-containing material based on the author's experience and discussions with other inspectors is 4% to 5% of the total area.

The total area of construction from 1950 to 1973 in Ontario is reported to be approximately 45,119,000 m^2, or 45,000,000 m^2. If one combines these figures, taking note of all the limitations discussed above,

the floor area of sprayed asbestos-containing materials in Ontario ranges from 900,000 m^2 to 4,500,000 m^2, with the most likely area being in the range from 1,800,000 m^2 to 2,250,000 m^2.

5. PIPE INSULATION IN ONTARIO BUILDINGS

No estimate of the extent of friable asbestos-containing pipe insulation could be compiled from the available data. As discussed earlier in this chapter generally a larger percentage of buildings contain other friable asbestos-containing materials (mainly pipe insulation) than contain sprayed materials. In the surveys reported in Table I the percentage with other friable materials range from 9.2% to 72.2%. These materials are often very limited in extent and are often confined to service areas. Some of the surveys included such material as ceiling tiles with a very low asbestos content or fire stop flaps. There is no information available indicating that these can release fibres to a building environment or whether they should be included in an inventory. Some genuinely friable materials however are often overlooked in surveys and therefore even the above percentages may be low. Thermal insulation products were used over a longer period of time than sprayed material and were often installed during minor renovations or building maintenance.

Although no estimate can be prepared on the extent of these other friable asbestos-containing materials in Ontario buildings, their use cannot and should not be ignored. This is particularly true because of the hazard of exposure to airborne fibres during demolition which is described in Chapter 7.

6. CONCLUSIONS

The estimation of the extent of sprayed asbestos containing material in Ontario have proven to be very difficult. The difficulties were due to the limited information available from current programmes of inspection and the lack of an accurate inventory of the total area of buildings in the province. An estimate was prepared but is subject to many approximations. These approximations and the assumptions necessary to prepare the estimate are described in detail in Section 4. The percentage of floor area containing sprayed asbestos-containing material was estimated to be in range of 2% to 10%, with the most probable percentage from 4% to 5%. This results in a possibly affected floor area ranging

from 900,000 m^2 to 4,500,000 m^2, with the most probable affected floor area from 1,800,000 m^2 to 2,250,000 m^2. These figures are very rough estimates and should be considered as such.

The extent of friable asbestos-containing pipe insulation or other friable asbestos-containing materials could not be estimated with the data available. The programmes of inspection reported in this chapter indicate that from 9.2% to 72.2% of the buildings inspected to date contain some form of friable asbestos other than sprayed materials. These materials may exist only in very small quantities or areas of a building and may in fact not pose any genuine potential for fibre release.

It is the author's opinion that a more detailed inventory of the extent of friable asbestos in Ontario would be of limited use to the Royal Commission on Asbestos. The main use of a complete inventory would be to alert the Construction Health and Safety Branch of the Ministry of Labour of upcoming renovations or demolition of specific buildings with these products to allow adequate inspection of the work. This would involve identifying the affected building by name and location and maintaining a file in the appropriate branch of the Ministry.

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CHAPTER 4

COST OF BUILDING INSPECTION

1. INTRODUCTION

The programmes of asbestos control in buildings described in Chapter 2 are dependent on the correct identification of friable asbestos installations that pose a potential hazard. Two very distinct routes of performing building inspections have been utilized by both public and private organizations. These are: (a) existing staff are trained in performing asbestos inspections and perform the inspections;

(b) an external consultant is hired to conduct the inspection and submit reports to the owner.

The costs of the first route are often hidden within the normal cost of building maintenance and any estimate may underestimate the time cost. The costs of the second route are easily identified and can be easily separated from other maintenance tasks. The cost of building inspection by each of these routes will be estimated in this chapter. If an incorrect or inadequate inspection is performed, necessary work may be overlooked or unnecessary or incorrect work may be performed. The effects of this will also be considered.

2. INSPECTION PERFORMED BY EXISTING STAFF

2.1 United States

The legislated programme of asbestos detection and hazard assessment in the United States (1) has generally been implemented using existing staff of the Local Education Agency (LEA). A recent publication of the U.S. EPA (8) has attempted to identify the cost of this programme. This information was collected by mailing letters of enquiry to schools and school districts requesting data on the square footage of each school surveyed, the amount of time spent surveying each school, the hourly rate of the surveyor, and the cost of bulk sample analysis. These data were initially used to develop costs on a square foot basis. This unit cost of inspection was found to be extremely variable, mainly due to the fact that estimated inspection times and costs for small schools approached those of larger schools. Therefore, only costs on a "per school basis" were reported in the final report.

Based on responses from 247 school boards, "the average cost of inspecting a school building was $21.04 with a minimum cost of $3.36 and a maximum cost of $156.00. The hourly rates of the inspectors were very low, in the order of $7.80 to $10.00 per hour. This cost obviously contains no allowance for overhead, administration services, or staff training and cannot be considered a realistic rate to compare with Canadian costs. The time required to perform a school inspection ranged from one-half hour up to twenty hours. These time estimates also apparently include no allowance for training time, travelling or reporting. The schools reporting in this survey ranged from small rural schools (less than 50 square metres) to large urban schools (greater than 50,000 square metres).

The relatively brief inspections and the professions of the inspectors (school administrators, maintenance employees, health specialists, or architects) indicate that these inspections were basically walk-through or brief surveys, intended only as preliminary inspections. That is, the inspection was intended mainly to show the presence or absence of friable asbestos materials. If the presence is confirmed, then a second follow-up survey to evaluate the installation, recommend corrective action, and mark the extent of the installation on building plans for tendering or control programmes would be needed. It has been the experience of the author and the Ontario Ministry of Education that these walk-through inspections may miss a large percentage of the friable asbestos, unless the inspectors have been adequately trained. The EPA report makes no mention of the training of inspectors.

The average cost of sample analyses was reported as $42.50 per sample. The recommended minimum number of samples from each school is 3, and the recommended maximum is 7. If one assumes that on average 5 samples are submitted from each school, then the average total cost for the inspection and analysis is $233.99. This would not include the follow-up inspection programme and marking of building plans for tendering.

2.2 Canada

Several of the most complete programmes of inspection, analysis, and control in Canada have been performed by the federal government. The three departments of Public Works, Transport, and National Defence, which together administer or control over 75 percent of the federally-owned buildings, carried

out the largest programmes, although most smaller departments carried out similar programmes. Due to the availability of suitable staff (architects, engineers, safety officers, building managers) and the dispersed nature of the federally owned buildings, a decision was made to perform all insepctions using existing staff and to use that staff to control and inspect the majority of any necessary remedial work. The staff of inspectors was trained by sending appropriate regional or site personnel to asbestos training courses. The total number of persons attending courses presented by either Ontario Research Foundation or the Association of the Wall and Ceiling Industry-International is as follows:

Public Works	35	attendees
Transport	19	"
National Defence	9	"
Indian and Northern Affairs	7	"
National Capital Commission	3	"
Health and Welfare	3	"
Correctional Services	3	"
Parks	2	"
Labour	2	"
National Research Council	1	
TOTAL	84	"

In order to obtain an estimate of the cost of the inspections, the programmes of Public Works Canada (PWC) (2) and the National Capital Commission (NCC)(3) will be considered. PWC represents a large owner with buildings distributed across Canada; NCC is a much smaller property-owner within a very localized region. These will be considered separately below.

2.2.1 Public Works Canada (PWC)

Public Works Canada owns or manages a total of approximately 12,950 buildings in Canada. These include administrative, operational (mail processing, garages, etc.), institutional (training centres), and residential buildings. An initial survey based on building plans, years of construction, and building types was performed to select buildings which required physical inspection. A total of 3,730 buildings were judged to require this inspection. A total of 35 PWC employees were trained to perform these inspections. The total cost of the training course for each attendee from PWC was estimated to

be approximately $2,000.00, including all expenses of travel, course cost, wages etc. On their return to their respective regions, inspections of the 3,730 buildings were performed by these persons. The inspections were performed largely in conjunction with scheduled inspections or site visits which essentially eliminated travel time and travel costs from the asbestos control programme. The time required to perform an inspection varies with the size of building and thoroughness of the inspection. Since a large number of PWC buildings were quite small, the average time of inspection was estimated not to exceed four hours. This estimate includes a provision for re-inspection of buildings once the presence of sprayed asbestos was identified by the preliminary inspection. The hourly cost of the inspectors could not be easily estimated by PWC and an assumption is made here that the cost will be the same as the inspectors for the Ontario Ministry of Labour's Construction Health and Safe Branch. This cost was estimated in 1980 to be $30.85 per hour (4). The total number of samples analysed for asbestos by a non-governmental laboratory was approximately 170, at a cost of $40.00 per sample. A larger (but unidentified) number of samples were analysed by Health and Welfare Canada. A very rough estimate of the total cost of this was $12,000, based on an estimate of 3 man-months for the analysis. These data are summarized in Table I.

TABLE I

COST OF INSPECTING PUBLIC WORKS CANADA NON-RESIDENTIAL BUILDINGS

Cost of Preliminary Survey of 10,500 Non-Residential Buildings		$ 20,000.00
Training of Personnel	35 x $2,000.00	70,000.00
Inspection Cost	4 hrs. x 3,730 x $ 30.85	460,282.00
Analytical Cost (Outside Laboratory)	170 x $ 40.00	6,800.00
Analytical Cost (Health and Welfare Canada)		12,000.00
TOTAL COST		$569,082.00
Cost per Building Inspected	(3,730 buildings)	$152.57
Cost per Non-Residential Building	(10,050 buildings)	$ 54.20
Cost per Square Metre	(7,794,790 m2)	$ 0.07

The cost per square metre is based on a total floor area of 7,800,000 square metres which includes the residential buildings. This unit cost is, therefore, a somewhat low estimate. The average cost of inspection per building is higher than the average of $21.04 obtained by the EPA study, but the analytical costs are lower due to fewer samples analyzed. The higher cost of the PWC inspection is due to the following factors:

(a) a more realistic wage rate has been used;
(b) training costs of inspectors are included;
(c) trained inspectors tend to do a more complete inspection;
(d) costs of re-inspection are included.

The programme of PWC has an additional advantage in that the 35 employees who have attended a training course will have obtained some training on the control and treatment of asbestos in buildings. These employees will be useful in implementing a programme of asbestos management and custodial control if it is needed, or overseeing any asbestos abatement contracts.

2.2.2 National Capital Commission (NCC)

The NCC manages or owns a total of approximately 250 commercial properties --largely retail stores, service establishments and institutional buildings. The NCC trained 2 employees for the programme of inspection, plus an additional maintenance employee.

The cost for training the inspectors amounted to approximately $2,500.00 per person. The employees selected as inspectors were involved in safety and engineering for the Commission and were thoroughly familiar with the buildings to be inspected. The inspections required a total of approximately 120 man-days. Very little sprayed material was found (only two installations) and a total of 4 samples were analyzed. A very considerable quantity of asbestos-containing pipe insulation was detected, however. This material was largely identified by building specifications, visual inspection, and the experience of the inspectors. This identification is not conclusive and should not generally be used. In this case, the costs of the remedial work were judged to be less expensive than the analysis of the samples. The visual identification of asbestos in pipe or boiler insulation is also usually more straightforward than with aprayed material. The same wage rate for the inspectors is used as for PWC. The data are summarized in Table II.

TABLE II

COST OF INSPECTING NATIONAL CAPITAL COMMISSION BUILDINGS

Training of Personnel	2 x $2,500.00	$ 5,000.00
Inspection Cost	120 x 7.5 x $30.85	27,765.00
Analytical Cost	4 x $40.00	160.00
TOTAL COST		$32,925.00
Cost per building (250 buildings)		$131.70

This cost is somewhat lower than the cost per building inspected by PWC, partially due to the small number of samples analyzed. The travel time and travel costs were also very low since the buildings of the NCC are largely within walking distance of its offices.

3. INSPECTION PERFORMED BY OUTSIDE CONSULTANT

The survey of school buildings has been the most active area of inspection and analysis in Ontario. Most school boards have used their own staff to perform an initial walk-through inspection and hired consultants to perform an in-depth analysis. The initial inspection was largely prompted by the Ministry of Education memoranda discussed in Chapter 2 and used procedures described in the Ministry of Labour booklet "Inspecting Schools for Asbestos" (5). The time for this initial inspection was estimated by the suburban Toronto Board (Chapter 2 Section 3.1.2) to be approximately 1 hour per school. This estimate was made for a relatively compact school district with rather large schools, but is considered by the author to be a reasonable estimate for most boards.

The cost of the second survey, which is much more in-depth and included a complete identification of asbestos-containing material on building plans, can be very accurately determined from data from school boards and a consultant who has performed numerous inspections. The initial inspection of the Toronto School Board (6) showed that approximately 50 of their 158 buildings required a detailed survey. This was performed by a consultant at a cost of $12,200.00. In all, 250 samples were taken for analysis and a typical cost of analysis of $40.00 per sample is used for estimating the cost.

The initial inspection was estimated by this Board to require approximately one man month. The Ontario Ministry of Labour hourly cost (4) is used for this initial inspection. The data is summarized in Table III.

TABLE III

COST OF INSPECTING THE TORONTO BOARD OF EDUCATION BUILDINGS

Initial Inspection	20 x 7.5 x $30.85	$ 4,627.00
Consulting Fee for Re-Inspection		12,200.00
Analytical Cost	250 x $40.00	10,000.00
TOTAL COST		$26,827.50
Cost per building (158 buildings)		$169.79
Cost per square metre		$ 0.02

This is similar to the cost per building calculated by PWC and the NCC using their own staff. The cost is kept low primarily due to the initial inspection performed by the Board staff which reduced the number of schools inspected by the consultant. The cost per square metre of area is very low at $0.02 due to the rather large and uncomplicated buildings inspected. Averaged over the 50 schools inspected by the consultant, the cost per school would be increased to $536.55.

The rural board described in Chapter 2, Section 3.1.4 hired an outside consultant to inspect every school. The cost of this study was approximately $15,000 for the entire board. There were 118 samples analyzed. Using the analytical cost estimate of $40.00 per sample, the cost per building was $597.57. The cost per square metre was approximately $0.10. The higher cost per square metre reflects the fact that the consultant inspected every school. In addition, the time and cost of travel were substantial for this rural board. The costs of this and other studies described here were covered by the Ontario Ministry of Education.

The Windsor Utilities Commission programme described in Chapter 2, Section 3.4 utilized an outside consultant for the entire inspection and

analysis programme (6). The buildings of the Commission were generally small, ranging from as little as 10 square metres to a maximum of 7,000 square metres. The buildings averaged approximately 500 square metres. The total charge for the inspection (including the analysis cost of 30 samples) averaged approximately \$175.00 per building, or \$0.34 per square metre. The low cost per building reflects the small size of the buildings and the compact geographical distribution (all within Windsor City limits). The costs on a square-metre basis are very high as the time for inspection of the small intricate building types is very high expressed on the basis of floor area.

The costs quoted above were obtained from building owners or their representatives. The time estimate for a walk-through type inspection and a thorough inspection including marking of building plans was also obtained from a private consultant (10). The estimated time for a preliminary survey for the presence of asbestos was estimated to be of the order of one hour per 1,000 square metres. This includes collation of results, preparation of reports and reasonable travel distance (usually 15-30 km). If a typical charge of \$40.00 per hour is assumed (the actual rates known to the author range from approximately \$25.00 per hour to over \$70.00 per hour), then the cost becomes \$0.04 per square metre. This would not include the cost of sample analysis. Sampling frequency is very subjective, but if friable material is found, a minimum of two or three samples must be taken in each building in widely separated locations. The results of this initial survey must be reported with drawings showing sample locations and an assessment of the condition of the material.

For a secondary survey, detailed enough to provide working drawings for contract tendering, the time required is significantly greater. Based on elementary and secondary schools, the time ranges from 0.12 to 0.5 hours per 1,000 square metre with an average of 0.25 hours. This would yield an average cost of \$0.10 per square metre. The lower end of the range is applicable to buildings which may contain only a small amount of sprayed material, as it is the average cost over the entire building. The higher end of the range is accounted for by buildings of greater complexity with more sprayed material where more careful systematic surveying is required. The consultant also

concluded that the cost for the survey of non-school buildings is somewhat greater as the buildings tend to be smaller and more complicated. This confirms the trend described above for the Windsor Utilities Commission.

4. COST OF IMPROPER INSPECTIONS OR RECOMMENDATIONS

The asbestos control industry is a relatively young industry which offers the opportunity of large profits to some individuals or firms. The inspection of buildings and the preparation of recommendations encompasses a number of fields or disciplines and requires a knowledge of building construction and inspection, environmental pollution, analytical methods of asbestos detection, provincial regulations,and even a slight knowledge of air handling systems and maintenance procedures. No professional body specifically licenses either contractors or asbestos inspectors. Competence in other fields of building inspection or environmental monitoring does not guarantee that a proper inspection programme or recommendation will be made.

A number of instances are known to the author where inadequate inspections or improper recommendations have been made in specific sites. Although none of these can be identified by name, a number of instances will be described which cover the major inadequacies of improperly performed inspections or improper recommendations.

(a) Incomplete Inspection

The use of inadequately trained or careless inspectors can lead to significant amounts of friable asbestos-containing material being overlooked. This was the case with at least two school boards in Ontario which used their own maintenance employees for the initial inspection. Although they reported little or no asbestos-containing material initially, a later inspection revealed substantial quantities in many buildings. This was largely located above suspended ceilings or in maintenance areas where it was not readily visible.

(b) Improper Inspection or Analysis

Any inspection programme must include a correct analysis of the suspect friable material. One case is known to the author where substantial

remedial work had been recommended to the building owner on the basis of a visual inspection and the use of the building specification. An analysis of the material just prior to commencement of the work indicated that the fireproofing contained no asbestos and the unnecessary remedial work was cancelled. An incorrect analysis can result in equally expensive mistakes. An example of this occurred in two different provinces when the same mineral wool fibre was incorrectly identified as being amosite by inexperienced laboratories using equipment which was not correct for asbestos analysis.

c) Improper Recommendations

The building owner usually places a great deal of reliance on the recommendations of an outside consultant. The recommendation of the appropriate remedial action requires a very subjective judgement and often more than one remedial action may be acceptable. There are cases known to the author where clearly incorrect recommendations have been made which have resulted in unnecessary work being performed. Two examples of this will be cited. In one instance outside Ontario, a contractor was called in to provide assistance to a school board. The contractor recommended removal of a stable cementitious installation containing less than 5% asbestos. The school board adopted this clearly unnecessary action and the contractor was awarded the work. In a second instance the representatives of a firm supplying an encapsulating material recommended encapsulation on a fireproofing spray which was approximately 2" thick and showed poor adhesion and extensive delamination. This was carried out and resulted in extensive delamination of the fireproofing.

No estimate of the cost of these inadequate inspections or recommendations will be made here. It is clear from these examples, however, that inspectors should have training and experience in asbestos inspection and should not be actively engaged in supplying materials or contracting services.

5. CONCLUSIONS

The cost of the inspection programmes described in this chapter vary significantly depending on many factors. The costs are summarized on a per square metre or per building basis in Table IV. There appears to be no systematic variation in the cost of inspection between the inspections performed by existing staff or inspections performed by an outside consultant or inspector. The costs per square metre agree reasonably well with the estimate of $0.04 per square metre for a preliminary inspection and $0.10 per square metre for an in-depth inspection provided by a consultant working in the field.

The results in Table IV indicate that a preliminary inspection, usually performed by the building owner (such as PWC or the Toronto Board of Education), can reduce the total cost of an inspection programme significantly by eliminating the need for a physical inspection in a large percentage of the buildings. This preliminary screening must be performed carefully in order to detect all buildings with a potential hazard which may require inspection. As an example of the savings possible, the cost per building physically inspected was similar for the Toronto Board of Education and the Rural Board, but the cost averaged over all buildings was approximately one-third as much for Toronto due to the preliminary screening. The cost per square metre ranges from $0.02 to $0.34 per square metre. This is largely due to differences in the building type or complexity, size of the building, and the use of this preliminary screening. In relatively small complex buildings such as Windsor Utilities, the cost per square metre will be high, whereas in rather large school buildings with quite uniform designs such as the Toronto Board of Education, the cost per square metre will be low. The inspection of a large number of buildings as opposed to one or two buildings will also reduce the average cost per building or cost per square metre due to economies of scale.

Since the cost of inspection can vary for any or all of the reasons described above, it is important that the figures be used with caution. In order to predict the cost of an inspection, persons using the figures provided should attempt to compare their buildings with the most similar building types of the programmes described.

TABLE IV

SUMMARY OF INSPECTION COSTS

ORGANIZATION	PERSONS PERFORMING INSPECTION	COST PER BUILDING $		COST PER SQUARE METRE ($. m -2)	
		Averaged Over All Buildings	Averaged Over Building Physically Inspected	Averaged Over All Buildings	Averaged Over Building Physically Inspected
Public Works Canada	Existing Staff	54.20	152.57	0.07	-
National Capital Commission	Existing Staff	131.70	131.70	-	-
Toronto Board of Education	Existing Staff and Consultant	169.79	536.55	0.02	-
A Rural School Board	Consultant	597.57	597.57	0.10	0.10
Windsor Utilities Commission	Consultant	175.00	175.00	0.34	0.34

It is essential that properly trained persons, whether existing staff selected for the inspections or consultants who specialize in asbestos-related work, be selected to perform the inspections. An incomplete inspection can leave potential problems undetected. An improper inspection or analysis can result in substantial expenditures for unnecessary work. An improper recommendation made out of inexperience or the desire to sell a product or services can also result in unnecessary work or incorrect work which actually exacerbates any potential exposure hazard.

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CHAPTER 5

COST OF CONTROL

1. INTRODUCTION

In order to plan any general asbestos abatement programme, an estimate of the cost of performing the various abatement procedures is necessary. While some published figures are available on the cost of asbestos control projects, the quoted costs per square metre of sprayed material vary enormously. There are also no figures available on the cost of asbestos pipe and boiler insulation removal. In addition, due to the experience gained in asbestos control and very severe competition in the industry, the cost per square metre of remedial work has tended to decrease over the past few years. This chapter will address the question of the cost of asbestos abatement work (removal, enclosure, encapsulation) based on recent American data and information from specific projects in Ontario in 1980 and 1981.

2. COST OF CONTROL IN THE UNITED STATES

The November 1980 publication of the U. S. EPA entitled "Economic Impact Analysis of Proposed Identification and Notification Rule on Friable Asbestos-Containing Materials in Schools" (1) collated a large amount of data on asbestos control. In addition to the costs of inspection and identification discussed in the previous chapter, a survey of costs of removal and replacement, encapsulation, and enclosure was performed. These data were based on a survey of contractors working in asbestos control. The relatively small number of respondents resulted in a wide statistical variation. Therefore, the average cost and range of costs will be presented here. Although the costs of asbestos control work varied significantly from state to state, there was no general geographical trend observed and all their data have been presented in Table I.

TABLE I

COST OF ASBESTOS CONTROL IN THE UNITED STATES (1980, U.S. DOLLARS)

Control Action	Number of Contractors Responding	Minimum Cost \$/m2	Average Cost \$/m2	Maximum Cost \$/m2
Removal	32	10.76	53.17	148.00
Disposal	18	0.43	3.77	16.68
Re-Insulating	35	3.77	8.39	16.14
TOTAL OF ABOVE OPERATIONS		14.96	65.33	180.82
Encapsulation	37	4.30	24.00	48.42
Enclosure	20	3.87	43.58	67.25
Marking	9	0.11	0.65	3.23

It is clear that some of the wide spread of costs for all abatement methods must be the result of work being performed on buildings of different design or characteristics. It is the author's experience that contractors' estimates on the same project may vary by a factor of three. The magnitude of the remaining variation in the responses is thus largely attributed to variations in building design. No attempt to investigate the nature of the work or building characteristics was made by the EPA report. If one considers the relative average cost for each of the control options, the following results are obtained:

Removal, Disposal and Re-Insulating	\$73.82 / m2
Encapsulation and Marking	\$24.64 / m2
Enclosure and Marking	\$44.23 / m2

Thus removal is almost three times as expensive as encapsulation and approximately one-and-one-half times as expensive as enclosure. The main advantage of removal is that the asbestos has been permanently removed from the building and no future possible hazard exists. This advantage cannot be compared with the short-term costs of removal, encapsulation, or enclosure.

These average figures are similar to earlier cost estimates (2) for an office building with a suspended ceiling where the asbestos fireproofing was found on the deck, beams, and ducts in the ceiling space. The estimated cost for encapsulating the fireproofing was \$29.05 per square metre of floor space, as opposed to \$45.19 for removal. Neither of these costs include an estimated \$15.17 per square metre for removal of the ceiling tile and replacement with new tile. This same source identified the cost of removal of insulation in a school gymnasium and hallway. This material was fully exposed with no duct work or suspended ceilings and no replacement insulation was required. These factors resulted in a low estimated cost for removal and painting (\$20.12 per square metre).

These figures indicate the difficulty of providing an estimate of the cost of asbestos abatement work. In the following sections the cost of specific projects will be presented and the factors influencing these costs will be discussed.

3. COSTS OF SPECIFIC PROJECTS IN ONTARIO

The costs of the removal, encapsulation, and enclosure of sprayed asbestos-containing materials in specific projects in Ontario were obtained from building managers, owners, or supervisors. The information was collected in late 1981 or early 1982 largely by personal interviews. A small amount of data was collected by means of a mailed questionnaire with a follow-up telephone call. The information collected was divided into three general categories and is presented in Tables II, III, and IV. Table II lists the costs of removal or enclosure in 15 public or private buildings or projects in Southern, Central and Eastern Ontario. Table III lists the costs of removal in 14 schools in Southern and Eastern Ontario. Table IV lists the costs of encapsulation of sprayed material in 2 schools in Eastern Ontario. All the asbestos abatement projects described in Table II were performed while the

TABLE II

COST OF CONTROL IN PUBLIC AND PRIVATE SECTOR, COMMERCIAL, OFFICE AND INDUSTRIAL BUILDINGS

(All work performed in isolated work area while remainder of building in use except otherwise noted; costs do not include architectural fees or monitoring; all costs expressed in 1981 dollars; all work performed in Southern or Eastern Ontario.)

Building Number	Control Action	Type of Installation	Accessibility	Total Floor Area of Work Site (m^2)	Duration of Work	Cost of Alternate Space ($)	Final Condition of Space	Lowest Cost $/$m^2$ Floor Space	Average Cost $/$m^2$ Floor Space	Highest Cost $/$m^2$ Floor Space	Comments
1	Removal	Fireproofing on deck and beams	Exposed	12,000	14 weeks	30,000 Relocation costs	Resprayed left exposed	54.88	-	-	1980, 400 people displaced, time and materials
2	Removal	Fireproofing on beams	Suspended ceiling	930	8 weeks	-	Respray; new ceiling	86.11	126.24	177.42	1981, small public room in large building
3	Removal	Fireproofing on beams	Exposed	160	2 weeks	Done on holidays	Resprayed	73.06	144.54	164.29	1981, small service room in large building
4	Removal	Insulation and acoustic on deck	Exposed	40	10 days	-	Painted	121.20	199.16	282.50	1981, small service room in large building
5	Removal	Condensation control on deck	Exposed; low ceiling	1,020	4 weeks	-	Resprayed	41.27	49.25	70.93	1981, storage area in basement
6	Removal	Insulation on ceiling	Exposed	450	6 weeks	-	Resprayed	110.84	-	-	1981, industrial building, crocidolite
7	Removal	Insulation on ceiling	50% exposed	5,300	5 months	45,000	Painted or new suspended ceiling	94.15	-	-	1981, material previously encapulated, many shut-downs, other contracts in parallel, time and materials
8	Removal	Acoustic on beams	Above plaster ceiling	450	4 weeks	Done on holidays	Painted	233.78	277.65	311.78	1981, dry power removal, above plaster ceiling
9	Removal	Fireproofing on beams	Suspended ceiling	41	1 week	-	Reinstall tiles	90.71	-	-	1981, small area of retail store, time and materials
10	Removal	Fireproofing on beams	No suspended ceiling	70	1 week	-	Painted	109.60	-	-	1981, small area of same store (#9), time and materials
11	Removal	Fireproofing on beams	Suspended ceiling	5,760	4 months	-	Painted	25.00	-	-	1982, large area of same store (#9)
12	Enclosure	Acoustic on deck	Exposed	800	10 days	-	Enclosed by suspended ceiling	37.50	-	-	1981, considered temporary measure, other necessary work in parallel
13	Enclosure	Acoustic on deck	Exposed	325	4 weeks	-	Enclosed by suspended ceiling	55.08	-	-	1981, service and store rooms, some removal as well (25 m^2)

TABLE III

COST OF ASBESTOS REMOVAL IN SCHOOLS

(All work performed in vacation periods; no cost for alternate space; all jobs in urban Southern and Eastern Ontario; disposal sites within 20 miles of job site, cost expressed in 1981 dollars)

School Number	Type of Insulation	Accessibility	Total Floor Area of Work Site (m^2)	Final Condition of Space	Lowest Cost $/$m^2$ Floor Space	Lowest Cost Per Column ($)	Highest Cost $/$m^2$ Floor Space	Comments
1	Fireproofing on 134 column headers	Suspended ceiling, air plenum	5300	Resprayed; reused tiles	30.87	1,220.	-	Performed 1980, Study of Educational Facilities (SEF) School
2	Fireproofing on 126 column headers	Suspended ceiling, air plenum	7500	Reprayed; reused tiles	29.00	1,726.	38.82	1981, SEF school
3	Fireproofing on 126 column headers	Suspended ceiling, air plenum	6600	Resprayed; reused tiles	28.75	1,506.	39.90	1981, SEF school
4	Fireproofing on 120 column headers	Suspended ceiling, air plenum	6600	Resprayed; reused tiles	36.91	2,030.	-	1980, Time and Materials, SEF school
5	Fireproofing on 90 column headers	Suspended ceiling, air plenum	4200	Resprayed; left exposed	16.33	762.	-	1980, SEF school
6	Fireproofing on 90 column headers	Suspended ceiling, air plenum	4200	Resprayed: reused tiles	14.47	675.	-	1980, SEF school
7	Fireproofing on 90 column headers	Suspended ceiling, air plenum	4200	Resprayed; reused tiles	13.72	640.	-	1980, SEF school
8	Fireproofing on beams, overspray	Suspended ceiling, air plenum	5600	Resprayed; reused tiles	21.96	-	39.18	1981, similar to SEF school
9	Fireproofing on beams & columns	Largely suspended ceiling	13900	Resprayed; new tiles, new lighting	69.28	-	87.27	1981, difficult job, plasterboard ceiling
10	Fireproofing on beams	Damaged suspended ceiling	370	Resprayed; new tiles	71.98	-	108.35	1981, high ceiling, gymasium
11	Fireproofing on beams & deck	Exposed	300	Painted only	138.95	-	-	1981, high ceiling, cramped conditions, fan room
12	Fireproofing on beams	Some exposed	1500	Resprayed; reused tiles	92.63	-	144.80	1981, small area of large school, fan room & classrooms
13	Fireproofing on deck & beams	Some exposed	4900	Resprayed; some tiles reused	106.43	-	154.59	1981, one-third of bldg. treated, fan room and classrooms
14	Acoustic on deck	Exposed behind mesh	1600	New acoustic panels	51.75	-	97.25	1981, one-third of bldg. treated

TABLE IV

Cost of Asbestos Encapsulation in Schools

(All work performed in vacation periods; no cost for alternate space; all jobs in urban Southern and Eastern Ontario; expressed in 1981 dollars; cost includes inspection and monitoring.)

School Number	Type of Installation	Accessibility	Total Floor Area of Work Site (m^2)	Lowest Cost $/$m^2$ Floor Space	Highest Cost $/$m^2$ Floor Space	Comments
1	Acoustic Spray	Exposed, 8-9 foot ceilings	3040	8.75	25.93	Approximately one half of school affected, 1981
2	Acoustic Spray	Exposed, 8-9 foot ceilings	5030	9.15	24.21	Approximately one half of school affected, 1981

remainder of the building was in constant use except for building number one. All work reported in Tables III and IV was performed during school vacation periods. It is felt that sufficient information is provided in the tables to indicate to building owners the expected cost of a particular asbestos abatement project. The lowest cost per square metre of work site (or per column for the Study of Educational Facilities schools) is the actual price paid by the building owner. If a number of bids were received the highest bid and average of all bids are also reported. All costs are adjusted to 1981 dollars.

Many factors contribute to the final price paid for any specific project. The costs of asbestos removal presented in Tables II and III in schools, public or private buildings range from $13.72 to $233.78 per square metre of the work site. Detailed analysis of the specific cases shows several causes of this wide cost range.

The lowest price was obtained in school 7. The material removed was located only on 90 column headers in a 4200 square metre school. The total area of material to be removed is therefore very much less than the area of the work site. The column headers were easily re-sprayed and the ceiling tiles were re-used. The work was performed in a very short period of the summer vacation when the building was unoccupied. The material was hidden behind a suspended ceiling but was otherwise readily accessible. The work was adequately inspected but performed under very general specifications by non-union labour. The contractor wished to establish a reputation in the field of asbestos removal and was therefore prepared to accept a low profit margin. These factors are a few of many which influence the contract price.

The highest project price per square metre was paid for building 8 in Table II. The material was applied as an acoustic treatment on steel beams above a partial plaster ceiling. This ceiling was not to be removed or damaged during the work. The total work area was small (450 m2) and was in a single, high-ceilinged room. Due to these constraints it was decided that dry removal offered the only reasonable control option. The specification and job inspection were quite rigid and all workmen had to be equipped with more effective, more expensive masks than are normally used on asbestos removal.

It has proven impossible in this study to quantify the effect of the numerous variables affecting the cost of an asbestos abatement project. If one considers the range of prices bid on any specific job listed in Tables II, III or IV the ratio between highest and lowest bid ranges from 1.26 to 2.96. These ranges indicate the impossibility of establishing an accurate estimate for even a single abatement project. The bidding process itself, being dependent on such non-quantifiable aspects as the condition of the local building industry and the judgement of the contractor, introduces a variation of costs within the same project almost as great as the variations between projects.

It is possible, however, to identify a number of factors which influence the cost of a project. Some of these can be controlled by the building owner whereas some are beyond his control. These factors will be the subject of the next section.

4. FACTORS AFFECTING THE COST OF ASBESTOS ABATEMENT - SPRAYED MATERIAL

The range of asbestos abatement costs presented in Tables II, III and IV is not dissimilar to the range determined in the aforementioned EPA report (1). A large number of factors are important in determing the price of an individual job. Considering the cost per square metre these include:

(a) project specifications;
(b) total area of project;
(c) control measure selected;
(d) accessibility;
(e) season of the year;
(f) original condition of work site;
(g) final condition of work site;
(h) quantity and type of asbestos-containing material;
(i) method of tendering;
(j) monitoring and inspection costs;
(k) specialized conditions requiring dry removal;
(l) type of building and building conditions;
(m) building open or closed during work;
(n) time allowed for contract completion;
(o) cost of alternate space;
(p) vagaries of contractor bidding;
(q) wage rates;
(r) Other factors.

No factor is consistently of most or least importance.. On any specific job any one of them may have a large influence. Each factor will be discussed with reference to the data presented in Tables II, III, and IV. The emphasis and most of the examples will deal with asbestos removal since this is by far the most widely used abatement technique.

4.1 Project Specifications

At the present time there is no generally accepted guide specification for asbestos abatement contracts. Part II of Asbestos-Containing Materials in School Buildings (3) contained a suggested guide specification for asbestos removal. This is currently being replaced by an updated version prepared under the auspices of the Association of the Wall and Ceiling Industry with input from many Canadian and American governmental agencies, contractors and consultants (4). These revised guide specifications used on specific projects are determined solely by the specification writer. Although the cost of the preparation of the specification is a small fraction of the total cost of an asbestos control project, the specification will have a profound effect on the final cost of the project.

It is clear that inadequate or unclear specifications may result in improperly performed but inexpensive work. This will result in hazards to the asbestos workers or to other occupants of the building. This type of inadequate specification is becoming less frequent as asbestos work becomes more commonplace. There is however an extremely wide range of quite acceptable specifications which can markedly alter the final price. A specification which calls for excessive precautions or air monitoring, or unnecessary work will result in the contractor submitting a high bid in order to cover every eventuality. It has been the experience of the author that an extremely rigid specification will result in a higher project cost while a less rigid one will produce a lower project cost and may indeed result in equivalent or superior contract performance. Many examples of the rigidity of specification writing which increase the cost of a project could be cited. As an example one specification called for air supply ducts to be cut off and capped prior to starting any asbestos removal. The asbestos removal contractor had to bring a sheet metal worker into the job site and ensure that he was familiar with the necessary asbestos work practices. The need for this action is not obvious since the air system was to be shut down and the air vents could be easily and effectively sealed with multiple layers of plastic and tape in the work area.

Specifying the method of sealing the duct would not improve the contract performance but would increase the cost of the project substantially.

The asbestos control work on schools 1, 2, 3, 6, and 7, was performed on a similar Study of Educational Facilities (SEF) schools in 1980 and 1981. The work involved removing dry applied fireproofing from column headers in an air plenum. In all schools the ceiling tiles were removed and replaced; all work areas were of similar size. The cost of removal and replacement with a non-asbestos product in schools 1, 2,and 3 ranged from $28.75 to $30.87 per square metre of floor space or $1,220.00 to $1,726.00 per column. The costs in schools 6 and 7 were $13.77 and $14.47 per square metre of floor space or $640.00 and $675.00 per column. Although several factors tended to decrease the cost of these last two projects (see sections 4.9, 4.14, 4.16) a major cause of the lower price was the very general specification used in the work. All five of the projects were performed under the control of the same experienced inspector and it is believed that all projects were safely and adequately performed. The tighter specifications for schools 1, 2,and 3 (with an increased amount of air monitoring) increased the price substantially with no significant advantage to the school board.

4.2 Total Area of Project

A significant part of the cost of an asbestos control project is the establishment of equipment, decontamination rooms,and enclosures. These costs and others remain substantially unchanged if a job site doubles in size. This results in a significantly reduced price per unit area on a larger job site. This can be seen in a general sense by comparing the costs of buildings 1 and 5 with buildings 3 and 4 from Table II. The larger jobs show a significantly lower cost per square metre than the smaller jobs. The cost per square metre for school 9 from Table III is still relatively low in spite of extremely difficult work conditions because of the large area treated. An even more clear illustration of the size effect can be seen by comparing buildings 9, 10, and 11 in Table II. These three projects are different phases of asbestos removal in the same retail store. The work was performed in each case under identical precautions and using the same men and work methods. The cost per square metre of work site decreases from approximately $100.00 per square metre for sites of less than 100 square metres to $25.00 per square metre for a site of over 5,000 square metres. The fact that jobs 9 and 10 were performed on a time and materials basis may have inflated the cost of the project somewhat but

the project was well controlled and this effect was considered minor (see Section 4.9).

4.3 Control Measure Selected

The data in Tables II, III, and IV contain little directly comparable data on the relative costs of asbestos encapsulation, removal, and enclosure. Only buildings 12 and 13 in Table II and schools 1 and 2 in Table IV are cited as examples of enclosure and encapsulation. In all four cases the asbestos containing material was fully exposed. This allowed easy access to the material and itself would have resulted in a relatively low cost had removal been selected (see Section 4.4). The timing of work and the method of tendering also reduced costs in the case of schools 1 and 2 in Table IV (see Sections 4.5, 4.9, 4.16). In spite of this, encapsulation is clearly the least expensive asbestos abatement option. The lowest costs ranged from $8.75 to $9.15 per square metre and even the highest tender was only $25.93 per square metre.

The costs of the two enclosure jobs (buildings 12 and 13, Table II) are significantly more than costs of encapsulation. It must be remembered that the total areas of enclosure were small in these buildings (325 and 800 square metres). This results in an increased cost per square metre (see Section 4.2). The cost of enclosure therefore seems to be intermediate to encapsulation and removal. If the EPA average figures are used the ratio of cost per square metre of encapsulation, enclosure, and removal are 1.0: 1.8: 3.0. As stated before the shorter-term cost advantage of encapsulation or enclosure must be weighed against the longer-term advantages of removal. These will not be considered here.

4.4 Accessibility

The ease with which the workers can reach the asbestos-containing material will have a great influence on the project cost. The less accessible the material to be removed, encapsulated, or enclosed, the more expensive the project. The accessibility includes such factors as ceiling height and obstructions to the workers. A suspended ceiling or the grid of a suspended ceiling will reduce the accessibility. This factor will also be considered elsewhere (see Section 4.6).

The influence of accessibility can be clearly seen in buildings 3, 5, 6, and 8 in Table II. Building 3 and 5 contained relatively accessible exposed fireproofing on the structural beams and deck respectively. The costs of $73.06 and $41.27 per square metre are significantly lower than building 6 which contained sprayed asbestos on the high ceiling of an industrial laboratory building. The construction of a suitable scaffold resulted in a greatly increased cost ($110.84 per square metre). Building 8 in Table II shows the highest cost per square metre of all projects in Table II. This is partly the result of the dry removal method selected (see Section 4.11) but is also due to the need to work above a plaster acoustic ceiling which remained in place during the removal.

4.5 Season of the Year

The seasonal timing of work can also have a significant effect on the cost of an asbestos control project. The summer period tends to be the active work period for asbestos abatement work largely due to work in schools. Therefore contractors tend to submit higher bids as they must use less experienced and hence less efficient workers and they are not willing to accept a low profit margin. At other times of the year when work is less plentiful many contractors will perform work with little profit margin merely to keep their full time workers employed. This factor cannot be clearly isolated from the data presented in Tables II or III as most of the work reported was summer work and other factors obscure the influence of the time of year.

4.6 Original Condition of Work Site

The preparation of a work site prior to actually removing, encapsulating or enclosing the asbestos-containing material is a significant part of the cost of any abatement contract. The original condition of the work site or material to be treated is determined by any of several factors. These include the nature of the floors or floor coverings, the presence of equipment and furniture (which may require moving or are fixed in position), the presence or absence of a suspended ceiling or the presence of a coating on the asbestos-containing material. The removal or protection of expensive building furnishings or equipment can be a major cost in an asbestos abatement project.

The low unit costs of the asbestos removal work in building 1 of Table II was due in part to the fact that the fireproofing was completely exposed and most of the building fixtures had been removed at the time the asbestos removal

contractor began work. The relatively high cost of the asbestos removal work in building 7, Table II can be explained in large part by the presence of a coating of paint which had been previously applied to the sprayed asbestos. This made wetting of the material very difficult which resulted in high airborne fibre levels, a slow rate of removal, and numberous job shut-downs. The need to protect the pre-existing plaster ceiling from damage in building 8 Table II also resulted in an increased unit cost.

4.7 Final Condition of Work Site

The amount of work required to replace fireproofing, acoustic materials, suspended ceilings or equipment in the work site will reflect directly in contract cost. Consideration must be given to the original purpose served by the asbestos-containing material and care must be taken to specify that the space is returned to that condition. The removal of fireproofing for example will affect the fire rating and usually requires re-fireproofing. Most project specifications call for the re-installation of the fireproofing by the same contractor who performs the removal or a sub-contractor to this contractor. This is usually the most cost effective method and is the route used in all buildings in Tables II and III which required re-fireproofing. In some instances the use of the building or building codes have changed so that replacement of the asbestos-containing material with asbestos-free material is not needed. This was the case with fireproofing removed in school 11, Table III and buildings 9, 10, and 11 in Table II. The insulating and acoustic materials removed from buildings 4 and 8, Table II were also not replaced; the beams were simply painted.

The installation of a suspended ceiling or replacement of tiles in an existing grid will also add costs. This is usually included in project specifications but is sometimes let as a separate contract. The cost of the two routes should be similar. This is also the case with re-installation of fixtures or furniture moved from the job site.

4.8 Quantity and Type of Asbestos-Containing Material

The costs per square metre presented in Tables II and III are based on the net floor area of the asbestos removal work site. In some of these sites the material may be applied only on the column headers, on the structural steel, on the deck, or may occur on any combination of these. This will result in substantially different areas of surface being treated than reported in the

tables. For example the Study of Educational Facilities schools (schools 1 - 7 in Table III) all occur at the lower end of the unit cost range largely because only the column headers were coated with asbestos-containing material. If the unit cost had been calculated using the area of asbestos-containing fireproofing removed, the unit costs would have been increased substantially. A major difference in the unit cost between schools 10 and 11 in Table III was due to the fact that school 10 had fireproofing on beams only and school 11 had fireproofing on both the deck and the beams.

The type or use of the asbestos containing material will also affect the contract price. Acoustic sprays are either fully exposed or partially exposed behind a mesh or a partial suspended ceiling in order to fulfill their function as acoustic materials. This will result in a lower cost of an asbestos abatement contract compared to fireproofing materials which are usually enclosed behind a suspended ceiling. In addition to this difference acoustic sprays are usually less and often very much less than ½" thick. Therefore if the material is removed the total volume of material to be removed, handled and disposed of will be less than if a greater thickness were being removed. Typically fireproofing sprays are greater than ½" thick and may be up to 3" thick.

4.9 Method of Tendering

Asbestos control work has often been undertaken due to public pressure and within a limited time frame. It has often not been possible to select contractors using the normal process of public tendering. In some other cases the building owner or specification writer has decided for reasons of confidentiality or other specific reasons that the process of public tendering would not be used to select the contractor. In some of these cases contracts have been performed on a time and materials or cost plus basis. In other instances several contractors have been invited to bid on a package of work which is then divided between the lowest bidders. This allows the work to be started and completed more quickly as more than one contractor is selected to perform the work. Both of these methods of tendering the work will also affect the cost of the project.

The cost of a project performed on a cost plus or time and materials basis is very much dependent on the integrity of the contractor and the degree of supervision exercised by the building owner. It is most commonly used where the asbestos control work must be scheduled to accommodate normal building

operations or other renovations. This type of intermittent work scheduling increases the time required for asbestos removal and makes the preparation of fixed price bids almost impossible. The projects in buildings 1, 7, 9, and 10 in Table II and school 4 in Table III were all performed on a time and material basis. The unit cost in the cases of building 1, 7, 9, and 10 are quite variable but considering the type of project, area of project (particularly in 9 and 10) and nature of the material to be removed (building 7) these costs appear within the range expected with public tendering. School 4 in Table III was a larger project than schools 5, 6, and 7 but was performed under the same project specifications. Expressed on a cost per unit area or cost per column basis it is clear that this project cost far exceeded the price which would have been expected from public tenders. This illustrates the care which must be exercised by the building owner in awarding a project on this basis.

The method of selecting contractors for several projects on the basis of a single bid prepared for a typical project or package of projects has also been used to speed the performance of asbestos abatement contracts. Often the building owner selects the low bidders on a selected project and then negotiates with them for other specific projects. This type of process was used for schools 5, 6, and 7 in Table III and schools 1 and 2 in Table IV. The work on schools 5, 6, and 7 in Table III was performed in a short period at the end of the summer vacation in 1980. The contractors were eager to gain experience in the asbestos removal field and a very low price was obtained by this school board. The encapsulation work in schools 1 and 2 in Table IV was also bid in a similar fashion. The price paid by the board of $8.75 and $9.15 per square metre is extremely low for correctly performed encapsulation work where full asbestos precautions must be followed. A representative of the board in question indicated that the contractors would not likely accept this price on future projects given the knowledge gained in this work. The method of tendering did produce a very low unit cost for the board in this instance however.

4.10 Monitoring and Inspection Costs

The cost of monitoring or inspecting an asbestos control project can be a major expense. This monitoring and inspection may be performed by an existing employee of the building owner or by a hired consultant. It is essential that asbestos abatement work be properly inspected to ensure that it is performed safely and completely. Ministry of Labour inspections may be

adequate to ensure the safety of the removal workers but will not ensure satisfactory contract performance.

The direct cost of the inspection and monitoring can vary significantly between inspection firms. Most of the inspections are charged on the basis of time expended, samples analyzed, distance travelled etc. While the unit cost of these services does not usually vary significantly between firms, the number of site visits, time spent, and samples analyzed can differ enormously. The frequency of inspection is usually laid out by the specifications or is left to the judgement of the inspector. In some cases specifications detailing the frequency of site inspections or air monitoring are drawn up by the firm providing those services. Both of these situations can lead to a very serious conflict of interest. Inspection costs known to the author have ranged from 4% to almost 30% of the contract cost. Although the percentage tends to be larger on smaller contracts, a figure in excess of 15% likely indicates a job which has been over-inspected or over-monitored unless some very unusual situation exists on the project. It is also important for the building owner to get more than one quotation for job monitoring and inspection. The total cost of inspection and monitoring tends to be much higher when competitive bids are not required. This higher total cost may be due to higher unit costs for services or for possibly unnecessary services such as continuous inspection or continuous air sampling. There is an indirect cost of the monitoring as well. If a contractor knows from previous experience that a particular monitoring firm will cause work to be slowed while every step is monitored and air samples are analyzed then this will reflect in the contract price. Although, from a safety standpoint a job cannot be over-inspected or over-monitored, from a cost basis this can certainly be the case.

4.11 Special Conditions Requiring Dry Removal

In some projects the usual techniques of wet removal can not be used. This is usually the result of electrical wiring which can not be disconnected, delicate equipment which cannot be adequately protected from water, or other building fixtures which would be damaged by water. In the one case of dry removal in building 8, Table II, the plaster ceiling could not be removed or damaged and dry removal was specified. The unit cost of $233.78 per square metre was clearly the highest of all projects shown. Although this is higher than usual for a dry removal project (see Section 4.4, 4.12), the cost of dry removal is in general much higher than wet removal. The power methods described in Chapter 1, Section 6.2, may reduce or eliminate this difference but at present dry removal is only specified when a higher project cost can be justified for other reasons.

4.12 Type of Building and Building Conditions

This is a very general factor which overlaps with many other considerations such as the area of the project, accessibility, original and final condition of the work site, and the area and type of asbestos-containing material. An experienced contractor or estimator will be aware of such factors as:

(a) Is the suspended ceiling easy or difficult to remove?

(b) Is the air handling system easily turned off and sealed from the work area?

(c) Does the presence of an adhesive coating make removal difficult?

(d) Are the rooms in the work area small (requiring additional erection of plastic on the walls or cleaning of the walls)?

(e) Are corridors suitable for easy movement of material or are there many stairs?

(f) Are there many services installed on the deck or beams which will obstruct the workers and require cleaning?

(g) If the asbestos-containing material is applied on the beams only is there significant overspray which will also need treatment?

(h) Does the work site have suitable power and water supply and are there shower or washrooms in the work area or nearby?

(i) Is there an elevator which can be used to transfer equipment and waste?

(j) Will the walls and floors be easily damaged if water gets on them through tears in the plastic? Will they be easy to clean?

Each one of these factors may become important on any specific project. As a general rule the treatment of asbestos-containing material in newer buildings which use a more simple design and construction technique is less expensive than in older buildings.

4.13 Building Open or Closed During Work

The asbestos control work in the school system is usually performed during the summer vacation period when the schools are not in use. Most of the projects occurring in buildings other than schools are performed while the buildings are still in use. In order to ensure that airborne asbestos is limited to the work site and does not contaminate other open areas of the building, additional precautions are often used in these cases. The use of asbestos-approved filter cabinets to draw air from the work site and produce a slight negative pressure is more commonly used when other areas of the building

remain open. This may tend to increase the cost.

If the building remains open during the contract it is often necessary to complete smaller work areas separately so that the functions of the building are not totally disrupted. This will effectively reduce the size of the work area, require more time in area preparation and clean-up,and increase the cost of the contract.

4.14 Time Allowed for Contract Completion

The time allowed for completion of a contract is an impossible factor to quantify but has a clear effect on contract price. The duration of the work can have several conflicting effects. If work must be done on a "3 shift a day" operation the cost may be increased by the need to pay overtime rates or shift premiums. Alternatively, if work can progress only very slowly due to the need to work in co-ordination with other contractors or normal building operations then the cost can be even more sharply increased. The most economical work rate usually allows the contractor to work a single shift a day using the same number of workers each day with no job delays while new work areas are prepared.

4.15 The Cost of Moving and Alternate Space

The normal occupants of the work site must be relocated during the asbestos control contract and then replaced at the completion of the work. This is of course not a consideration in the school system where work has been performed during vacation periods. As shown in Table II the duration of work may be as little as 10 days if the work site is small or as long as 5 months if the work site is large or if problems are encountered. Only in exceptional instances is a building completely vacated during work. Only in building 1 of Table II were employees moved outside their building into available space elsewhere. Owners of buildings 1 and 7 in Table II estimated the cost of alternate space to be \$30,000 and \$45,000 respectively. These costs are only 5% and 9% of the contract price. The true cost of the disruption of employees and building operation is much greater due to the lost employee time during the moving periods. These costs are not included in the cost per square metre quoted in Table II as the costs are absorbed in general company overheads.

Since employees are often temporarily located elsewhere in the building, the moving of office equipment is often performed by the building maintenance personnel and it is difficult to estimate the moving cost if an outside moving firm is employed. The cost of packing, moving, and unpacking the contents of a 4-metre by 5-metre office within the same building and later returning it to the finished work area was estimated to be in the region of $300 to $400 (8). If the office must be relocated to a nearby building and later returned to the original location, the cost was estimated to be approximately $600 (8). The cost of this move would therefore be in the range of $15.00 to $30.00 per square metre. This can be a significant portion of the total cost of the asbestos control procedure.

4.16 Vagaries of Contract Bidding

The preparation of a cost estimate by a contractor relies heavily on the skill and judgement of the estimator. The ratio between the maximum and minimum cost quoted on any individual job in Tables II, III, and IV range from 1.26 to 2.96. The difference between the lowest bidder, who is awarded the contract, and the next lowest bidder is, on occasion, as much as 50%. A low bid is sometimes made for a specific reason (for example to shut out other contractors or to keep workers employed) but may be due to an error in judgement. This is the likely case in schools 1 and 2 of Table IV. The contractor on school 8, Table III is also known to have lost money on that contract. Most contractors will attempt to speed up work and reduce expenses if it becomes clear during the course of a contract that costs will exceed the contract price. It is at this time that the greatest surveillance is required by the inspector. Several asbestos control contractors now operating in Ontario often submit bids 40% or 50% below other bidders. The prices are such that it is questionable whether correct work practices can be followed. In these cases the work will cost the building owner only that agreed price but it is essential to have a skilled inspector to ensure correct performance of the contract. This is often not the case and the contractors can often get away with inferior work. As a general rule contractors are pre-qualified in some fashion before bids are accepted on asbestos control project. The pre-qualification requirement usually requires proof of previous contracts completed, training course attended, equipment available, and familiarity with regulations. If these pre-qualification criteria are satisfied, if

sufficiently concise specifications are used,and if an experienced inspector is employed then correct completion of the contract should be ensured and it is in the building owners advantage to obtain the lowest price. It is usually an advantage to obtain the maximum number of bids on any project if public tendering is used.

4.17 Wage Rates

A large portion of the contractor's expense in an asbestos control project is the labour cost. Although only a small number of contractors employ union labour much of the work is performed for fair wage rate employers. In some cases, particularly for short duration summer work, non-union labour or students have been used. While this may provide a substantial cost saving it is open to severe abuse. At the very least asbestos control workers should be provided with an absolute minimum of several hours training. According to the proposed Ontario regulations for asbestos all asbestos workers require a pre-placement and periodic medical examination (5). Both the employee training and medical examination are often neglected by employers whose full-time workers are in short supply. This is the responsibility of the employer however, and beyond the need to have closer inspection and control, this should not affect the building owner.

4.18 Other Factors

A number of other factors have been suggested to affect the cost of asbestos control projects. If the waste disposal site is distant from the project, cost may increase. In Ontario, a sufficient number of sites exist so this is not a significant factor. If a bulk waste handling system is employed only a few sites will accept the waste and the distance becomes significant.

There is a trend for the range of bids on asbestos control projects to decrease as contractors become more experienced. The price has tended to decrease from the early projects to the present time. The only exception to this has occurred where contractors made low bids in order to get into asbestos removal work or where the contractor made a low bid out of inexperience or ignorance of the work methods necessary. The cost of work performed in 1982 probably increased much less over work performed in 1981 than the Construction Price Index would indicate.

COST OF CONTROL PROJECTS ON NON-SPRAYED ASBESTOS

Although the vast majority of asbestos control work has involved sprayed insulation, fireproofing or acoustic materials some work has been performed on other friable asbestos-containing material. The costs of the encapsulation of asbestos-containing fire flaps and dampers and the removal of asbestos-containing thermal block insulation will be discussed briefly here.

5.1 Encapsulation of Fire Flaps and Dampers

As discussed in Chapter 2, there is some controversy over the need to perform any control measure on asbestos containing fire flaps and dampers. In spite of this several boards have encapsulated the asbestos-containing material or removed the material completely. As an example Dufferin Peel Roman Catholic Separate School Board spent $109,000 to encapsulate (or remove badly damaged) asbestos-containing material on 740 fire dampers (6). This cost of approximately $147.00 per damper is very reasonable compared to other bidders on the same project and other projects known to the author. The units were removed completely from the school for encapsulation where possible and then re-installed after the sealer had dried. The low cost per unit is partially due to the large number of units treated which reduced the cost per item.

5.2 Removal of Pipe and Boiler Insulation

Very few large projects involving the removal of pipe and boiler insulation have been performed in Ontario using the correct work procedures described in Chapter 1. Some small asbestos pipe insulation removal projects have been completed (such as the Windsor Utilities Commission) but the majority of work has involved repair or recovering of the insulation. At the present time information is available to this study on only one large asbestos thermal pipe and boiler insulation removal project.

This project involved removing up to 4" of asbestos-containing block from approximately 1,350 square metres of piping and hoppers. The material had been applied in several layers and was well coated with canvas and paint. The material was only removed due to demolition of the structure. The work was well monitored and performed using wet removal methods. (See Chapter 6, Section 4.) The cost of removal and disposal was approximately $150.00 per square metre. A price had earlier been obtained from a wrecking contractor who

estimated the cost at less than one-third of this price if asbestos removal precautions were unnecessary. The cost of removal was also close to double the cost of installing new insulation according to the contractor.

These limited figures make it clear that the removal of asbestos containing pipe and block insulation can also be a large expense to the building owner. Many of the factors influencing the treatment of sprayed asbestos will also affect the price of pipe and boiler insulation removal.

6. CONCLUSIONS

The information presented in this chapter indicates the high but variable costs of asbestos abatement work. The average cost of removal and replacement; encapsulation and marking; and enclosure and marking have been estimated by the EPA to be \$73.82, \$24.64, and \$44.23 per square metre respectively (1980 prices quoted in U.S. dollars). The average cost of asbestos removal (and replacement where necessary) in Ontario was found to be \$70.54 per square metre with a standard deviation of \$50.58 per square metre (1981 dollars). This large standard deviation indicates the extremely variable costs of asbestos removal. Insufficient data were available to calculate an average cost of encapsulation or enclosure based on Ontario prices. The EPA found the ratio of encapsulation: enclosure: removal to be 1.0: 1.8: 3.0. A similar ratio would be expected in Canada. The cost of encapsulation of fire-dampers in the one project discussed was \$147.00 per unit. The cost of the removal of pipe and boiler insulation was \$150.00 per square metre.

A number of factors have been identified in this chapter which influence the cost per unit area of asbestos control work. Due to the number of these factors and the non-quantifiable nature of many of these factors no matrix of costs could be established for various control measures in specific buildings. Some of the factors reflect the characteristics of the building and cannot be controlled by the building owner. Other factors which can be controlled or affected by the owner also can have a large influence on the project costs.

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CHAPTER 6

HAZARD IDENTIFICATION AND AIRBORNE ASBESTOS FIBRE LEVELS

1. INTRODUCTION

A number of air monitoring studies have been performed to determine the fibre levels in the air of buildings containing friable asbestos-containing materials. These have been described in Chapter 1 and will not be discussed here in detail. As was pointed out in that and subsequent chapters optical microscopy (using the phase contrast microscope usually with NIOSH method P & CAM 239) is not an appropriate technique for use in non-occupational settings. This is primarily due to the limit of resolution of the optical microscope and because the procedure does not identify the fibres observed. The transmission electron microscope (TEM) has a greater magnification factor and incorporates fibre identification to overcome these two deficiencies of the optical methods. The results of TEM analyses reported in Chapter 1, while indicating that buildings containing sprayed asbestos often have higher than background airborne asbestos fibre levels, could not be used to determine potentially hazardous buildings. The measured airborne asbestos fibre levels were indicative only of the levels at the precise time of sampling and hence were quite variable even within one building.

A number of organizations, recognizing the limitations of the PCM or TEM air sampling results, have attempted to use the results of a visual inspection and bulk analysis in an algorithm to produce a numerical rating of any asbestos-containing installation. The algorithms generally provide a single number which in some way should assess the relative hazard of the particular installation. The factors considered important in these hazard assessment indices have been described in Chapter 1, Section 4.1. Three of the hazard assessment indices or algorithms have been included in the Appendices to this report. The most widely known was published in draft form by the Environmental Protection Agency in 1979 (1). It is included here as Appendix A. The Ferris Index (named after Dr. B. Ferris, who developed the scale) was used to rate the potential contamination in Massachusetts public schools (2). The Toronto Board of Education has used a modified Ferris Index on all schools in its jurisdiction using a single

inspector to maintain uniformity (3). The scale is included here as Appendix B. The U.S. Navy Risk Evaluation Index (4) is included here as Appendix C. This index incorporates physical observations of the material and installation (friability, accessibility, condition and activity in the area) with the percentage of asbestos to produce a single level of exposure factor. These factors have an extremely large spread from 0.0002 to 470,000. In all three indices a larger number indicates a greater potential risk.

The EPA is currently performing a study to correlate measured TEM airborne asbestos fibre levels with their Exposure Index (5). The full results of this work have not yet been published. The preliminary results indicate that airborne concentrations of asbestos are higher in sites with friable asbestos-containing materials than in areas with no asbestos and higher than in ambient air. Information obtained from the EPA after the completion of the study described in this chapter [May 1982 (6)] indicate that there is no correlation between the TEM measured levels and the EPA draft exposure index. As a result of this, the EPA is considering withdrawing the draft Exposure Index and substituting a factor which describes only the ease with which fine fibres can be released from the surface. The recent EPA results do confirm that asbestos fibre concentrations in buildings insulated with sprayed asbestos-containing material are significantly above ambient levels. In general the levels detected in the recent EPA study are above the levels reported in Table IV Chapter 1. In this chapter the three hazard assessment indices described above will be applied to nineteen buildings containing sprayed friable materials. The results of the algorithms will then be compared with extensive TEM air sampling in these buildings.

2. TEST METHODS AND RESULTS

The inspections of the nineteen buildings were performed by either one or two experienced inspectors. Since the evaluation of the various factors is subjective and depends on the judgement of the inspector a number of buildings representing typical installation were visited by two inspectors. This ensured that there was some consistency in rating the variables among the buildings. The results of the three hazard indices or algorithms on the nineteen buildings inspected are presented in Table I.

TABLE I

RESULTS OF THREE HAZARD INDICES IN EVALUATING NINETEEN BUILDINGS

Building No.	EPA Exposure Assessment Algorithm	City of Toronto Board of Education	U.S. Navy Level of Exposure
1	18	1025	1.0
2	16	975	0.37
3	12	675	0.0002
4	81	1750	30,000.0
5	16	950	1.0
6	54	1600	33.0
7	20	900	0.37
8	20	900	0.37
9	36	1050	5.8
10	12	750	0.37
11	24	825	2.1
12	71	1675	92.0
13	24	850	2.1
14	54	1675	92.0
15	24	1075	1.0
16	6	550	0.0002
17	24	1000	1.0
18	54	1475	33.0
19	36	1425	92.0

The results of the inspection which produced the ratings presented in Table 1 are not reported in detail to respect the wishes of some of the building owners and since they are individually of little use in providing additional information. In order to provide a better understanding of the type of building which will produce a particular rating however, three buildings representative of a wide variety of buildings will be described and rated according to the three hazard indices.

Building Type A would be an office building with a wet applied or cementitious fireproofing applied on the steel deck and beams above a suspended ceiling. The material, which contains 5% to 10% chrysotile is in good condition with no water damage or signs of deterioration or de-bonding. The ceiling space serves as an air plenum but is only rarely entered to perform any maintenance activity. The sprayed material has only a low friability and there is little evidence of dust above the suspended ceiling. If these factors are substituted into the algorithms presented in Appendices A, B, and C, the following results are obtained:

EPA Exposure Number	2
Toronto Board of Education Rating	550
U.S. Navy, Level of Exposure Factor	0.0002

At this level the EPA scale would indicate that deferred action (or management and continuing surveillance as described in this study) is appropriate. Neither the Toronto Board of Education nor the U.S. Navy Exposure Index provides any guidance for action or inaction at various levels, being used only to rank projects in order of concern. The U.S. Navy Level of Exposure Factor rather than the Hazard Index Number is used here since neither the number of assigned occupants or the occupancy duration would be expected to have a bearing on the measured airborne fibre levels. The level of exposure factor has therefore been used to be directly comparable to the other algorithms. In determining the priority of remedial work it may be useful to consider the number of occupants removed from a potential hazard for a certain expenditure. Thus, areas with high occupant density would tend to be subject to abatement work before low occupant density areas. This factor could be considered in any of the hazard assessment indices.

Building Type B would be an office building with some areas containing computing, telecommunications,or similar equipment. The sprayed fireproofing is installed on the deck and beams above a suspended ceiling. The dry applied (or fibrous) fireproofing has been shown to contain 25% to 35% chrysotile with the balance largely mineral wool and non-fibrous binder (cement). The material is in quite good condition except for minor water damage and areas where it has been damaged due to the installation of wiring or electrical conduit above the suspended ceiling. The material is accessed only rarely, mainly during the maintenance work or rewiring described above, but some tiles are regularly moved aside to provide increased air movement from equipment rooms into the ceiling space air plenum. These factors would produce the following ratings:

EPA Exposure Number	28
Toronto Board of Education Rating	925
U.S. Navy Level of Exposure Factor	120

The EPA Exposure Number would indicate that the material should be encapsulated, enclosed,or removed. Which of these options is chosen would be determined by factors such as the cost of each method, the potential for future damage,and the feasibility of each method in the particular building. These considerations are described in detail in Appendix A.

Building Type C would be an industrial facility, warehouse building or garage. The sprayed asbestos-containing material is located on all of the ceiling or roof surfaces largely for insulation or condensation control. It contains more than 90% amosite asbestos with the remainder being non-fibrous binder. This material,which is very friable,was applied under the trade name LIMPET TM. There is some water damage due to water leaks but the material is not easily reached due to the height of the ceiling. The material is fully exposed to the occupants of the building in this high activity area. The rating factors for this structure would be:

EPA Exposure Number	90
Toronto Board of Education Rating	1,775
U.S. Navy Level of Exposure Factor	170,000

The EPA Exposure Number would indicate that the sprayed material should be removed.

All air monitoring was performed using the transmission electron microscope (TEM) method. The TEM samples were collected by drawing known volumes of air through 37 mm. diameter cassettes holding 0.4 or 0.2 mm pore size Nuclepore filters backed up by 0.8 mm pore size cellulose mixed ester filters and cellulose back-up pads. The direct carbon coating extraction replication technique was used to prepare the Nuclepore polycarbonate membrane filter samples for analysis. In this technique the active surface of the filter is coated with a thick film of vacuum evaporated carbon. Chloroform is used as the solvent in a Jaffe Washer to dissolve the Nuclepore filter, leaving the deposit from the original air sample trapped in the carbon film supported on copper specimen grids. The prepared grids were examined in a transmission electron microscope (TEM) at a magnification of approximately 20,000. The TEM technique incorporates fibre identification so that only asbestos fibres are reported. In addition to examining the morphology of each fibre, in the TEM the crystal structure of a fibre is examined by means of selected area electron diffraction (SAED) and the elemental composition of a fibre is obtained by energy dispersive X-ray analysis (EDXA). During examination of these filter samples, asbestos fibres were classified as either chrysotile or amphibole. Chrysotile fibres were identified by their characteristic tubular morphology with confirmation by SAED and EDXA whenever possible. The identification of amphibole was by SAED combined with EDXA.

The results of the analysis for asbestos fibres of all lengths and fibres longer than 5.0 µm are reported in Table II. It must be realized that no measurement technique can demonstrate a zero result. They can only show that concentrations are less than the detection level of the analysis. This detection limit is dependent on the volume of air sampled but is usually in the range 0.001 f.mL-1 0.004 f.mL-1 in the present work. However, for ease of presentation if no fibre was detected in the analysis a figure of 0.0 is shown in the Table. The number of samples analyzed per building ranged from a single sample to seven individually collected samples.

3. CORRELATION OF AIR MONITORING RESULTS AND HAZARD INDICES

The original intention of this chapter of the study was to determine whether a correlation existed between these exposure indices and the measured airborne asbestos fibre levels measured by the TEM. Consideration of the data in Tables I and II indicate immediately that no correlation

TABLE II

RESULTS OF AIR MONITORING
TRANSMISSION ELECTRON MICROSCOPY IN NINETEEN BUILDINGS

Building No.	Number of Samples	Asbestos Fibres of All Lengths		Asbestos Fibres >5.0 µm	
		f.mL-1	ng.m-3	f.mL-1	ng.m-3
1	4	0.0007	0.589	0.001	0.275
2	5	0.006	2.959	0.0 (a)	0.0 (a)
3	1	0.004	0.026	0.0	0.0
4	3	0.003	0.067	0.0	0.0
5	5	0.0	0.0	0.0	0.0
6	3	0.015	1.743	0.001	0.067
7	5	0.01	0.017	0.0	0.0
8	3	0.004	0.313	0.0	0.0
9	2	0.202	0.004	0.0	0.0
10	4	0.010	0.045	0.0	0.0
11	7	0.009	11.002	0.001	10.571
12	3	0.023	3.339	0.003	1.247
13	2	0.010	0.027	0.0	0.0
14	4	0.016	2.683	0.002	1.450
15	1	0.059	8.000	0.0	0.0
16	2	0.003	0.012	0.0	0.0
17	4	0.027	0.703	0.0	0.0
18	1	0.010	0.130	0.0	0.0
19	4	0.001	0.016	0.0	0.0

(a) The figure 0.0 indicates that no fibres were detected; the concentration is therefore below the detection limit for that sample.

would exist between these factors and the asbestos fibre concentrations for fibres longer than 5.0 μm. Air monitoring performed on the 19 buildings (a total of 64 samples) detected airborne asbestos fibres in only 5 buildings (a total of 17 fibres longer than 5.0 μm) or 11 air samples. The fibre levels reported here are far below current environmental guidelines. Most occupational standards are based on fibres longer than 5.0 μm (7) and the Ontario Ministry of the Environment guideline is also based on fibres longer than 5.0 μm. However, it was clearly not possible to obtain any correlation with these data since the five buildings with non-zero fibre concentrations are not invariably the buildings with the highest hazard indices, and the buildings with zero fibre concentration have hazard indices well above zero.

When one considers asbestos fibres of all lengths, the large number of zero readings is eliminated and it is no longer possible by inspection to determine whether a correlation exists between the results in Tables I and II. The results for asbestos fibres of all lengths are plotted versus the hazard rating in Figures I through VI. Figures I and II plot the concentration in fibres per millilitre (f.mL-1) and in nanograms per cubic metre (ng.m-3) versus the EPA Exposure Number. Figures III and IV plot the same variables against the Toronto Board of Education Rating. Figures V and VI plot the same variables against the U.S. Navy Level of Exposure Index. The rating factor for each of the three building types described earlier is shown by the letters A, B and C on the abscissa.

The results appear to be quite random and no obvious correlation exists between the airborne asbestos fibre concentration (expressed in ng.m-3 or f.mL-1) and any of the three hazard indices. The calculated correlation coefficients were shown to be as follows:

f.mL-1	vs	EPA Exposure Number	0.076
ng.m-3	vs	EPA Exposure Number	0.003
f.mL-1	vs	Toronto Board Rating	-0.102
f.ng.m-3	vs	Toronto Board Rating	0.023
f.mL-1	vs	U.S. Navy Factor	0.012
ng.m-3	vs	U.S. Navy Factor	-0.129

These results confirm the visually apparent lack of correlation between the rating factors and the asbestos fibre concentrations.

FIGURE I

Concentration (f.mL-1) Asbestos Fibres of All Lengths versus the Calculated EPA Exposure Number (Letters A, B, and C on abscissa indicate exposure number of building types A, B and C described in text)

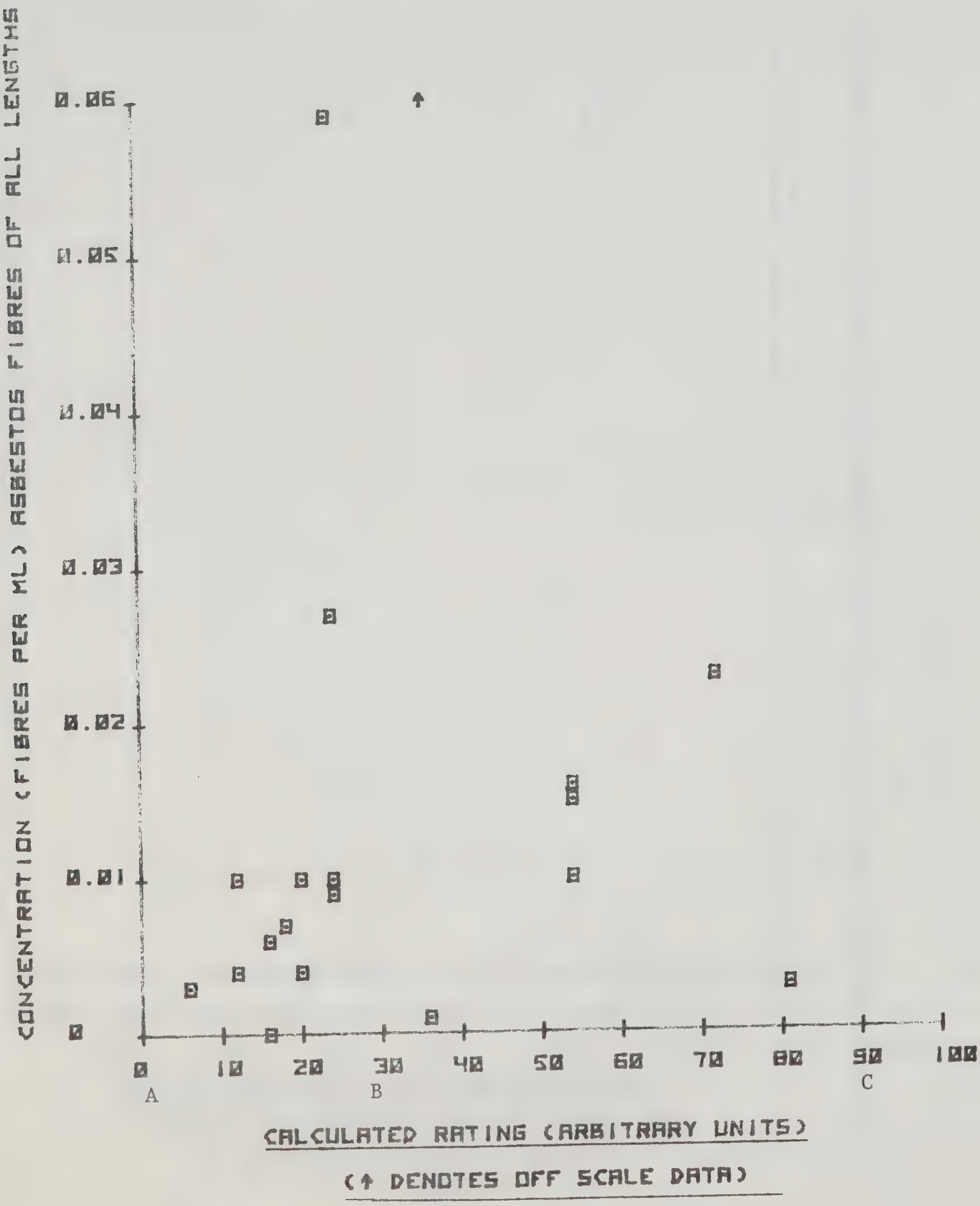


FIGURE II

Concentration (ng.m-3) Asbestos Fibres of All Lengths versus the Calculated EPA Exposure Number (Letters A, B, and C on abscissa indicate exposure number of building types A, B and C described in text)

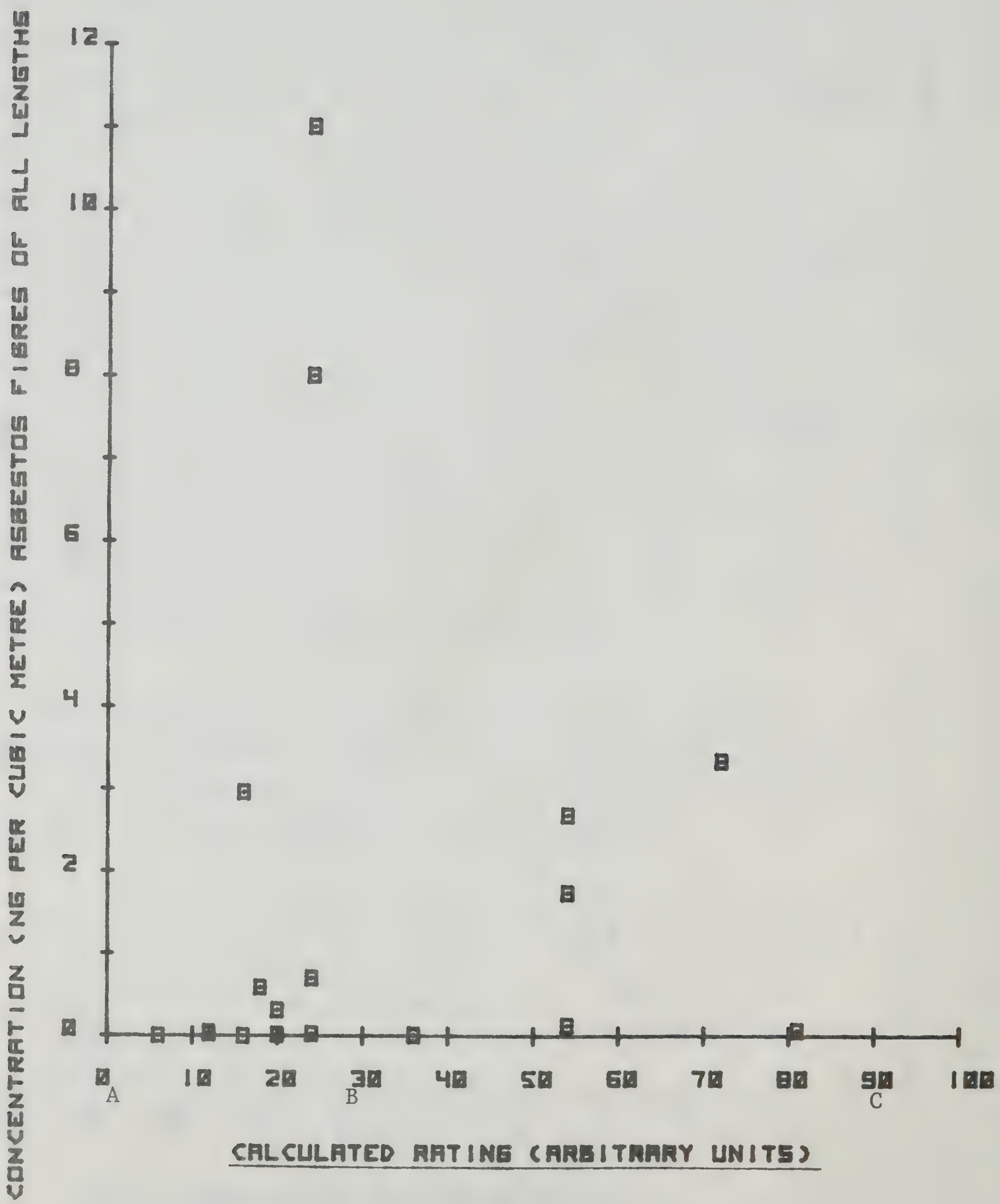


FIGURE III

Concentration (f.mL-1) Asbestos Fibres of All Lengths versus the Calculated Toronto Board of Education Rating (Letters A, B and C on abscissa indicate ratings of building types A, B, and C described in text)

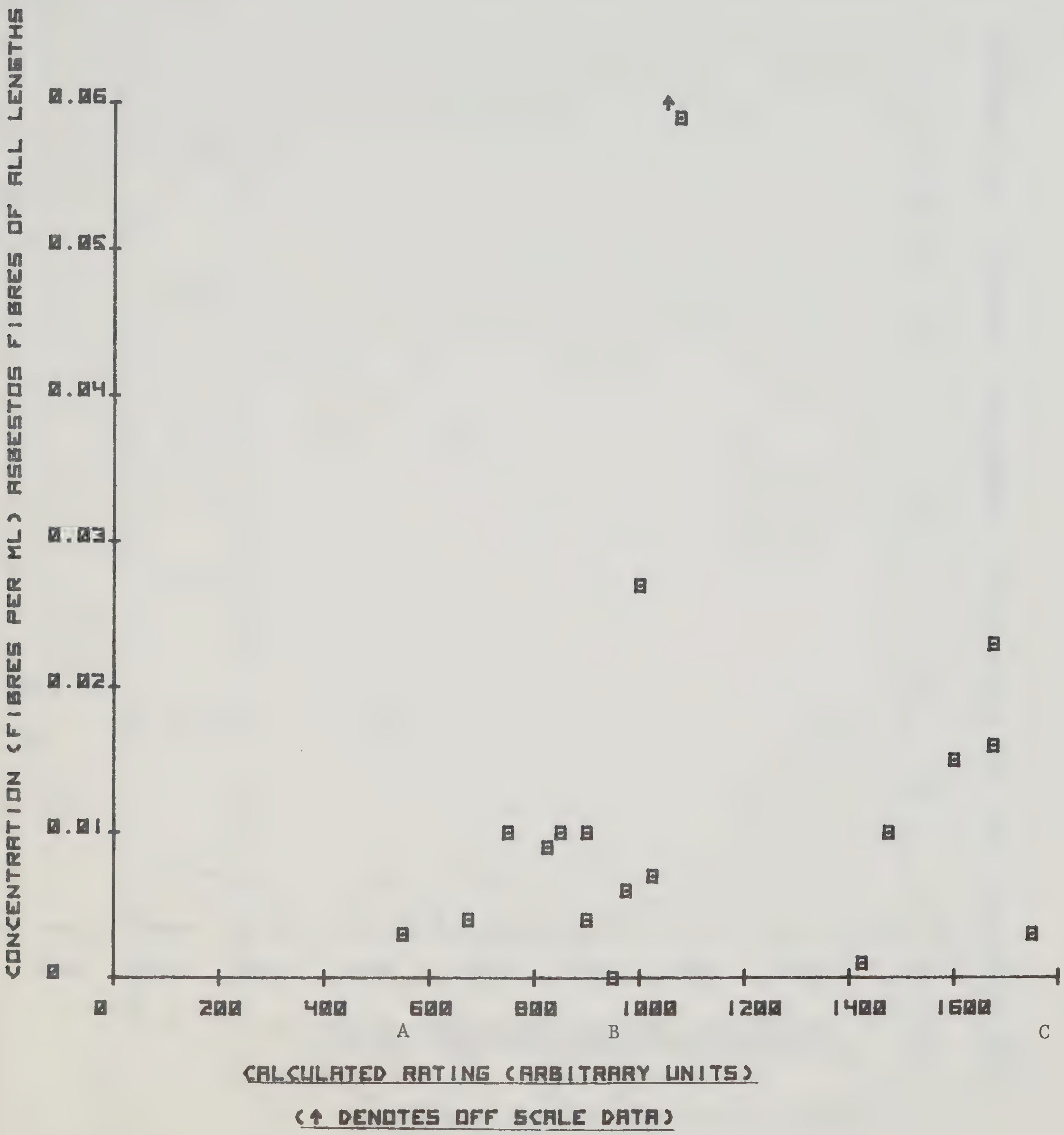


FIGURE IV

Concentration (ng.m-3) Asbestos Fibres of All Lengths versus the Calculated Toronto Board of Education Rating (Letters A, B and C on abscissa indicate ratings of building types A, B, and C described in text)

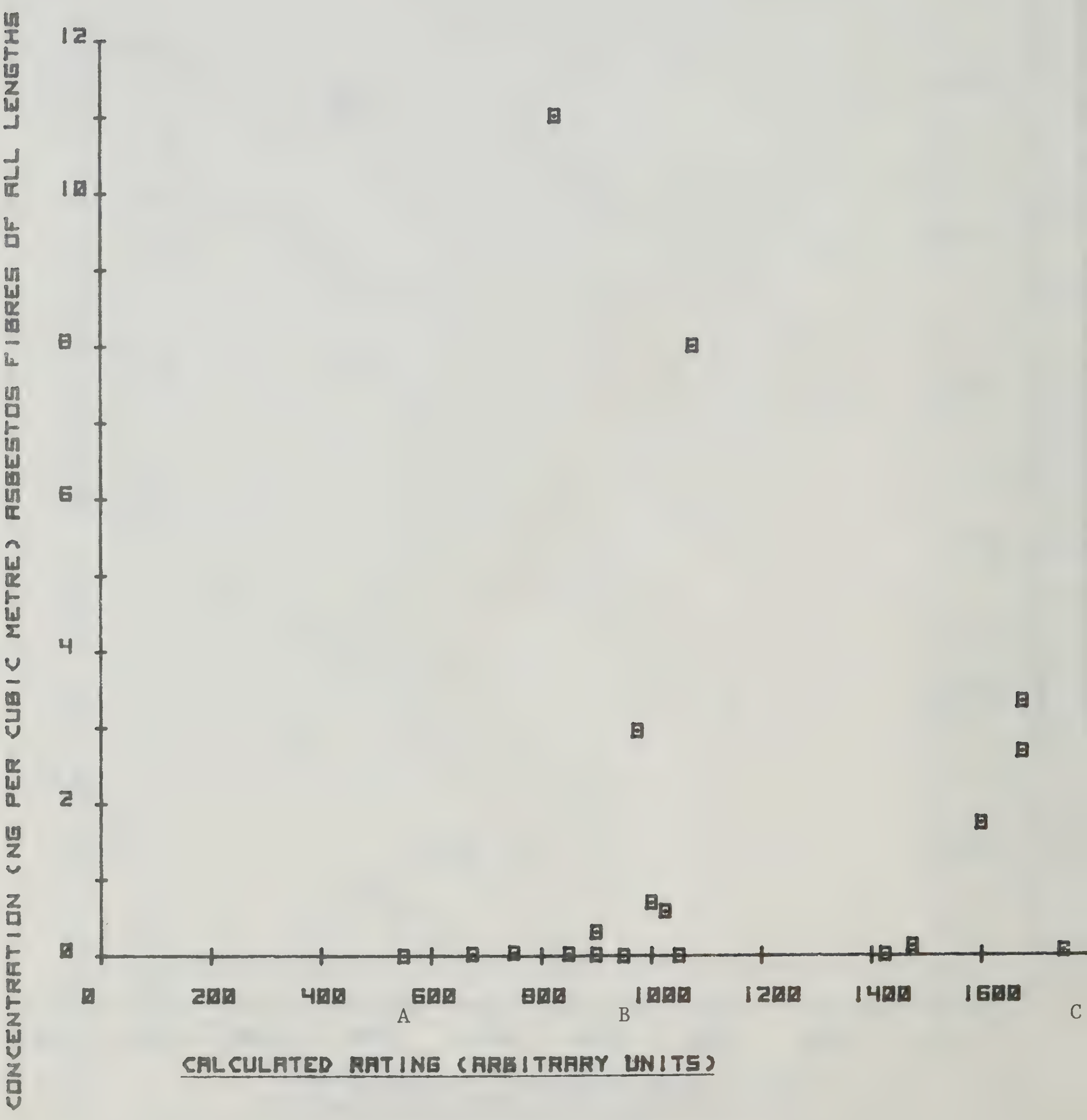


FIGURE V

Concentration (f.mL-3) Asbestos Fibres of All Lengths versus the Calculated U. S. Navy Level of Exposure Factors. (Letters A, B, and C on abscissa indicate exposure factors of building types A, B and C described in text).

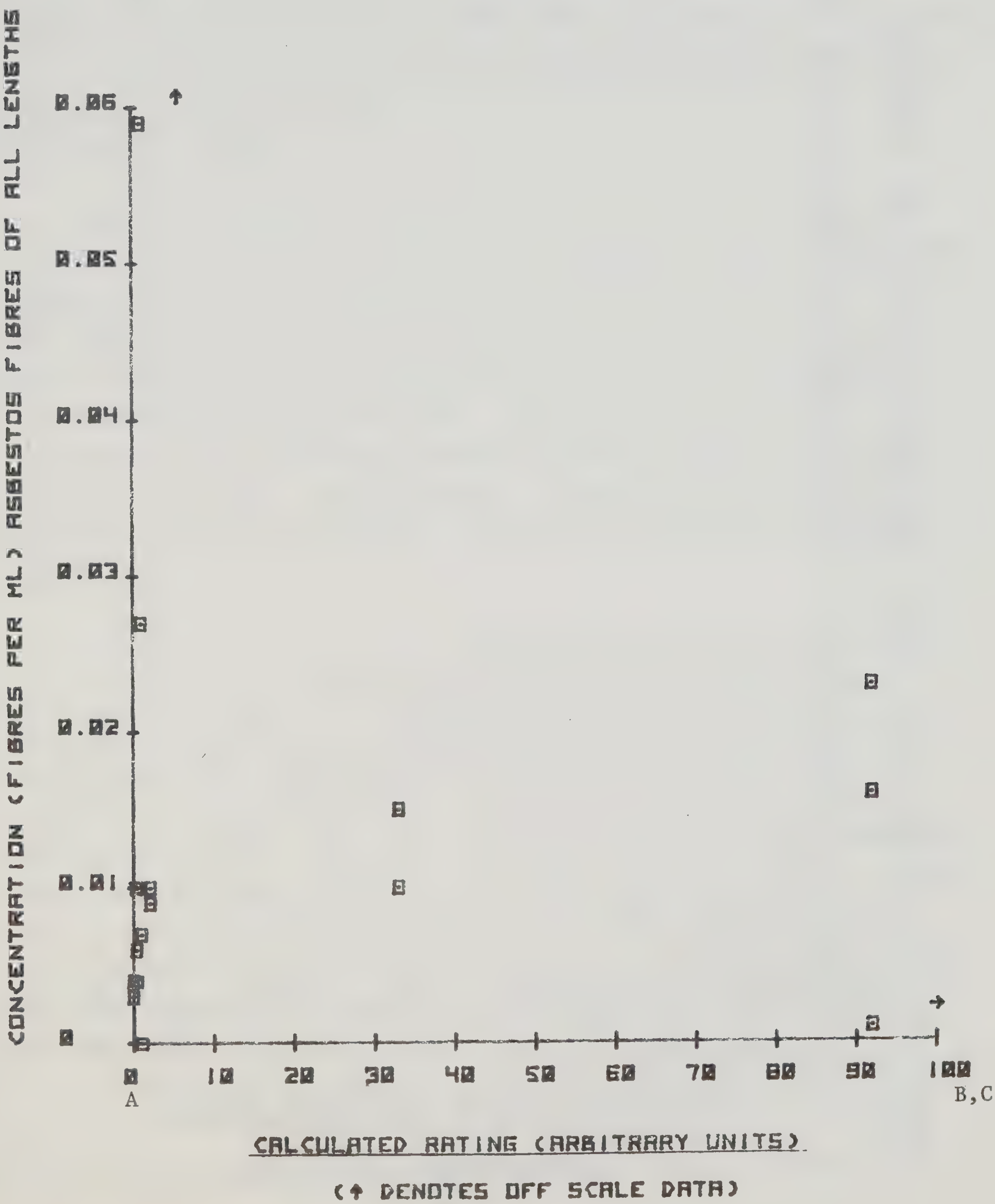
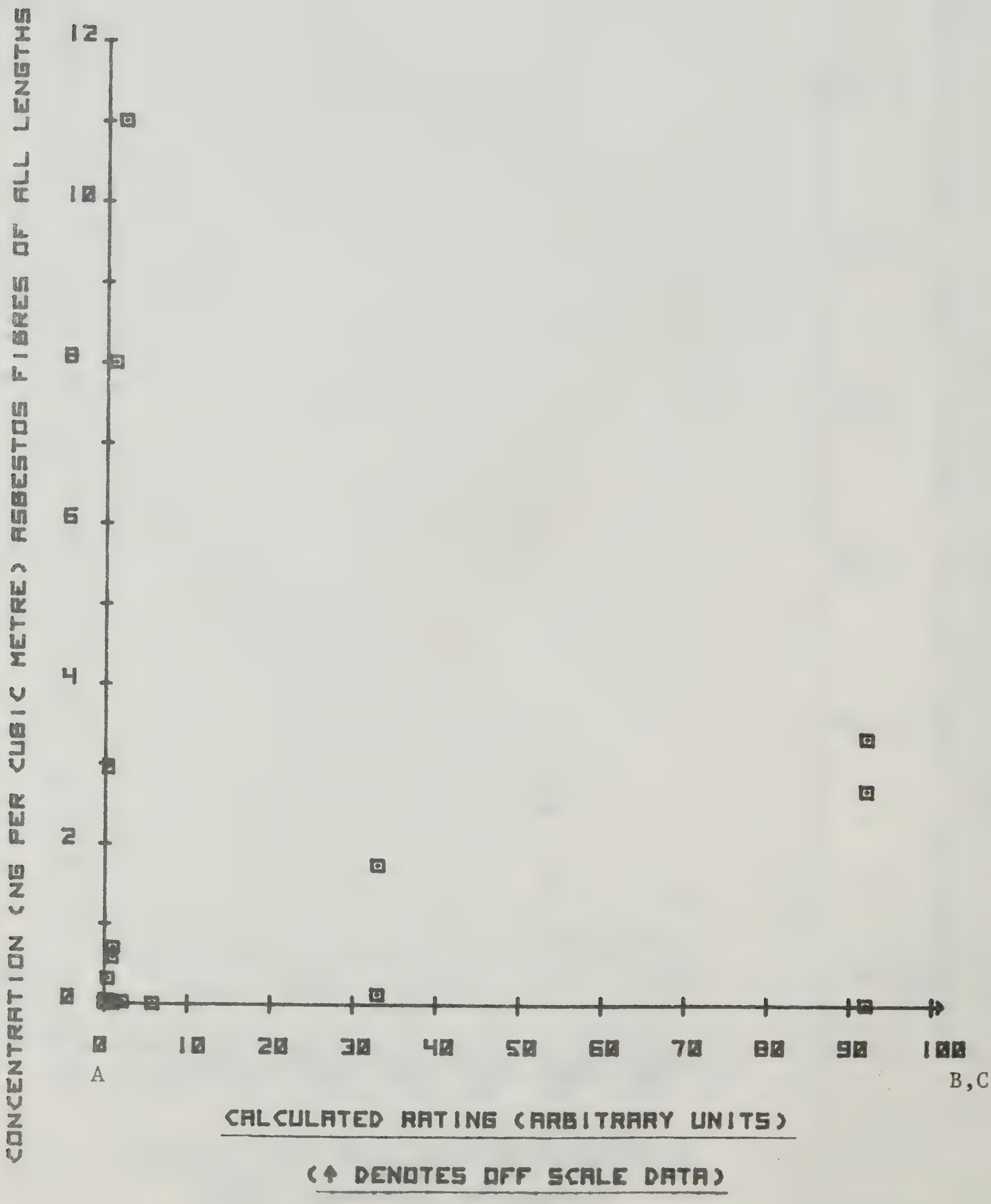


FIGURE VI

Concentration (ng.m-3) Asbestos Fibres of All Lengths versus the Calculated U. S. Navy Level of Exposure Factors. (Letters A, B, and C on abscissa indicate exposure factors of building types A, B and C described in text).



4. DISCUSSION

The results of the air monitoring presented in this chapter indicate that at the time of sample collection, the airborne asbestos fibre levels were quite low. The concentrations of asbestos fibres longer than 5.0 um were in all cases less than 10% of the current Ministry of Environment guideline of 0.04 f.mL-1. It is important that the results of this limited air monitoring not be considered in isolation from air monitoring reported elsewhere or from other sections of this study. The results cannot be used to prove that friable asbestos products in buildings pose no risk to the general occupants of a building or to the maintenance staff in a building for a number of reasons.

Firstly the asbestos fibre concentrations are representative only of the airborne asbestos fibres at the time of sampling. The TEM sampling was generally performed during normal building operation when no disturbance of the friable asbestos-containing material was occurring. As the results in Chapter 7 indicate, some maintenance activities can produce very elevated airborne asbestos fibre concentrations even when performed under strict supervision with the appropriate asbestos related equipment. The general occupants of a building could be exposed to asbestos fibre concentrations significantly above those reported in Table II if such work is performed routinely.

A second factor to consider concerning the presence of sprayed asbestos relates to the demolition or renovation of buildings. Any renovation or demolition of a building containing sprayed asbestos-containing material or other friable products has the likelihood of producing levels of airborne fibres far above the currently accepted occupational standards. The results reported in Chapter 7 from a number of asbestos removal sites confirm this conclusion. Results reported in Chapter 1 from a variety of sources indicate that high fibre levels are produced even during minor renovations such as removing pipe lagging, moving ceiling tiles,or moving wiring in a ceiling space where sprayed asbestos is present. These results clearly indicate that all friable asbestos-containing materials must be removed prior to renovations or demolition. The Ontario Ministry of Labour guidelines (7) specify that, "Prior to the demolition, partial demolition or renovation of a building or similar structure, all

friable asbestos material shall be removed using the procedures referred to under 'Asbestos removal'." The guidelines therefore do not call for immediate asbestos abatement work, but will quite reasonably require appropriate precautions if asbestos material is to be disturbed. Therefore eventually all friable asbestos-containing material will be removed and the only choice given to the building owner is to the timing of the work.

The final factor which must be considered is the relationship between these data and data presented by others. The fibre counts and concentrations reported here are generally lower than reported by other workers such as the studies presented in Table IV of Chapter 1. This may be a characteristic of the type of asbestos installations in Ontario buildings, building characteristics or even such factors as quantity of make-up air used in the buildings examined. The data presented in Table II of this chapter were generally collected in buildings with suspended ceilings. A recent unpublished study in schools performed for the EPA (5) indicated that a mean of 231.43 ng.m-3 of asbestos was detected in 48 sites examined. The majority of these sites were in buildings containing a sprayed acoustical product fully exposed to the occupants. The 19 buildings examined in the current study were not scientifically selected and the results therefore can not be generally applied to all types of asbestos installations. In comparing the results of any two studies, it is important to consider such factors as the methods used in selecting buildings for study and the air sampling and analytical methods used.

In spite of these limitations, it is clear that the airborne fibre levels measured in this study do not correlate with the three hazard evaluation indices in common use. This conclusion confirms the result of the aforementioned EPA study (6).

It is the opinion of the author that the degree of maintenance activity, or plans for future renovation or demolition of an area with asbestos-containing materials are most important in determining the appropriate choice for an asbestos control programme. This will be commented upon after the data collected during asbestos control programmes are discussed in Chapter 7.

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CHAPTER 7

EFFECT OF CONTROL MEASURES

1. INTRODUCTION

The large expenditures to remove, encapsulate, or otherwise control fibre release from friable asbestos-containing material can be justified only if the measure selected does indeed reduce measured fibre levels or future possible exposure. Some work has been reported on the effect of asbestos removal on fibre levels (1) and air monitoring is often used as a method of ensuring suitable contractor performance. The data have not been collected or reported systematically however and are of little value. In order to determine the effect of an asbestos removal project on measured fibre levels in the building, eight projects involving the removal of sprayed material were monitored using optical microscopy, transmission electron microscopy, and visual inspections. This monitoring was performed before the asbestos-containing material was disturbed, during the work, and after the clean-up. One additional project involving the removal of asbestos-containing boiler insulation block was monitored using similar techniques. No enclosure or encapsulation work was monitored as no projects suitable for monitoring were ongoing at the time of data collection.

Since the control option of management and custodial control is in common use, several operations involving work on or in the vicinity of sprayed asbestos-containing material were also monitored. This was intended to indicate the exposure levels to which maintenance workers or other building occupants may be exposed during normal maintenance operations.

2. ASBESTOS FIBRE LEVELS DETECTED DURING INSPECTION AND MAINTENANCE

Often when sprayed asbestos-containing material is located above a suspended ceiling, building owners have delayed performing asbestos removal or encapsulation. In these instances a programme of management and custodial control has been instituted to reduce the exposure of maintenance workers and other building occupants to air-borne asbestos fibres. The reduction of elevated airborne fibre

levels produced by impact during entry above the suspended ceiling and the protection of the workers during this entry are the major aspects of these control programmes. In order to determine typical levels produced during entry above a suspended ceiling two different operations were monitored. The first involved removing screw-in type or glued ceiling tiles, performing an inspection in the ceiling space, sometimes taking a sample of the sprayed material and replacing the tile. These activities required little or no contact with the asbestos-containing material.

The second operation involved a considerable disturbance of the material in the ceiling space in preparation for the installation of new wiring. The workers were removing snap-in metal tiles, vacuuming these and adjacent tiles and cleaning any other accessible dust-laden surfaces. Any direct contact with the sprayed material on the deck was inadvertent but, since the work above the ceiling was quite extensive, was impossible to prevent completely.

2.1 Inspection Above Suspended Ceiling

The activity monitored in this case involved inspecting sprayed asbestos-containing material and occasional sampling of the material. The sprayed fireproofing contained more than 90% amosite asbestos and was located only on the structural steel. The suspended ceiling was of two different types. In corridors it consisted of perforated transite tiles backed with paper-wrapped fibreglass insulation. These tiles were removed by unscrewing the transite board and moving the fibreglass insulation to the side. In the rooms, 8" x 8" tiles were glued to a solid Gyprock ceiling. In order to enter the ceiling space a small square had to be cut in the ceiling.

2.1.1 Test Methods

The inspector and an observer were equipped with personal air pumps to collect samples for phase contrast microscopy (PCM) and for transmission electron microscopy (TEM). The PCM samples were collected by drawing known volumes of air through 37 mm. diameter cassettes holding 0.8 micrometre (um) pore size cellulose mixed ester filters backed by a cellulose back-up pad. The TEM samples were collected

by drawing known volumes of air through 37 mm. diameter cassettes holding 0.4 or 0.2 μm pore size Nuclepore filters backed up by 0.8 μm pore size cellulose mixed ester filters and cellulose back-up pads.

The cellulose mixed ester samples were analyzed by phase contrast microscopy by NIOSH method P+CAM239 (2). In this method, sections of the filter are rendered transparent by a clearing agent and examined by a light microscope set for phase contrast conditions. Particles longer than 5 μm and with length to width ratios greater than 3 to 1 are considered fibres. The fibres are counted until 100 fibres are detected or until 100 microscope fields are examined. The NIOSH asbestos monitoring procedure was developed for use in the asbestos processing industry where airborne fibre levels are typically 1 fibre $.mL^{-1}$ and almost all airborne fibres are asbestos. Results where other fibres may be present should be interpreted with caution because the procedure does not identify the fibre. Only fibres thicker than about 0.3 μm can be resolved by the light microscope and included in the count, regardless of their lengths. The lower limit of reliable quantitation for the method reported by NIOSH is 0.1 fibre $.mL^{-1}$. Any results below this limit have concentrations that should be interpreted as indications of the lack of high levels rather than as accurate figures.

The direct carbon coating extraction replication technique was used to prepare the Nuclepore polycarbonate membrane filter samples for analysis. In this technique the active surface of the filter is coated with a thick film of vacuum evaporated carbon. Chloroform is used as the solvent in a Jaffe Washer to dissolve the Nuclepore filter, leaving the deposit from the original air sample trapped in the carbon film supported on copper specimen grids. The prepared grids were examined in a transmission electron microscope (TEM) at a magnification of approximately 20,000. The TEM technique incorporates fibre identification so that only asbestos fibres are reported. In addition to examining the morphology of each fibre, in the TEM the crystal structure of a fibre is examined by means of selected area electron diffraction (SAED) and the elemental composition of a fibre is obtained by energy dispersive X-ray analysis (EDXA). During examination of these filter

samples, asbestos fibres were classified as either chrysotile or amphibole. Chrysotile fibres were identified by their characteristic tubular morphology with confirmation by SAED and EDXA whenever possible. The identification of amphibole was by SAED combined with EDXA.

2.1.2 Results and Discussion

The results of the analyses are presented in Table I. The TEM results are presented in more detail in Appendix K. The PCM results are reported in fibres per millilitre air ($f.mL^{-1}$). The results of the analysis by TEM are reported in both fibres per millilitre air ($f.mL^{-1}$) and nanograms per cubic metre air ($ng.m^{-3}$). The results for TEM are reported for asbestos fibres of all lengths and also for asbestos fibres greater than 5 µm.

Fibre levels by optical microscope were significantly above background levels in each of the personal samples. The levels detected were less than the proposed occupational level (5) but were still significantly above levels normally measured in non-occupational settings. In order to identify the nature of the fibres detected the TEM was used on samples collected simultaneously.

Low levels of small asbestos fibres, less than 5 µm in length, were detected in each of the two background samples and in the personal sample taken above the ceiling as the inspector worked. Low levels of short chrysotile fibres are normally present in the outside environment. In addition, a few small asbestos fibres, both chrysotile and amphibole, are frequently detected as a result of the known low level contamination of the unused air sample filters. No asbestos fibres exceeding 5 µm in length were detected in any of these three samples. Therefore, at the time of sampling, the levels of airborne asbestos fibres longer than 5 µm in these areas were below the detection limit for each analysis.

The concentration of asbestos fibres of all lengths in the room while the inspector worked above the ceiling was 0.39 $f.mL^{-1}$. This is very significantly elevated above the background levels. Amphibole

TABLE I

Air Monitoring Results During Inspection Above Suspended Ceiling (See Notes in Text)

Sample Location	Optical Microscopy (PCM) $f.\ mL^{-1}$	Transmission Electron Microscopy: Total Asbestos Fibres $f.\ mL^{-1}$	Total Asbestos Fibres $ng.\ m^{-3}$	Asbestos Fibres >5.0 μm $f.\ mL^{-1}$	Asbestos Fibres >5.0 μm $ng.\ m^{-3}$
Personal sample on Inspector	0.31	0.152	14.7	<0.02	-
Personal sample on Observer	0.15	0.39	460.7	0.016	420
Background area sample in building	<0.009	0.066	3.3	<0.008	-
Background area sample in building	0.009	0.092	1.6	<0.008	-

asbestos fibres longer than 5 µm were present at the analytical detection limit of 0.016 $f.mL^{-1}$. No chrysotile fibres longer than 5 µm were detected in this sample, and therefore the airborne concentration of these fibres was below the detection limit of 0.016 $f.mL^{-1}$.

In TEM analyses of air sample filters, the detection limit (concentration equivalent to 1 fibre detected) is directly dependent on the volume of air which has been sampled. In the case of the samples collected while the inspector worked, the sampling time, and therefore the total sample volume, was limited by the duration of the actual inspection activity. As a consequence of this low air volume, the detection limit for the anlyses of these two samples is higher than the limit for the analyses of the background samples. The concentration of amphibole asbestos longer than 5 µm (0.016 $f.mL^{-1}$) is due to the detection of a single amphibole fibre.

All existing legislation and environmental guidelines concerning permissible fibre concentrations are expressed in terms of those fibres having lengths exceeding 5 micrometres. For control of the asbestos fibre concentrations in workplace atmospheres, the Ontario Ministry of Labour (MOL) currently proposes a time-weighted average exposure limit of 0-5 $f.mL^{-1}$ (fibres longer than 5 µm) where amosite is known to be present. The specified measurement technique is phase contrast optical microscopy. In this technique all particles are reported which are visible in phase contrast illumination at a magnification of 450 and have lengths greater than 5 µm and aspect ratios of 3 to 1 or greater. There is no provision for identification and only particles sufficiently wide to be observed will be reported, regardless of length. Because of these limitations, this measurement technique is generally applied only where most airborne fibres are likely to be asbestos, such as in the asbestos industry.

For control of asbestos fibre concentrations in the outside atmosphere, to which the general public may be exposed continuously, the Ontario Ministry of the Environment (MOE) applies a "guideline" of 0.04 $f.mL^{-1}$ (fibres longer than 5 µm), measured by transmission electron

microscopy. The TEM technique incorporates fibre identification so that only asbestos fibres are reported. Guidelines have not yet been established for air quality in general occupancy buildings. Small chrysotile asbestos fibres are always present in any air sample, even in the outside environment away from cities.

Low levels of asbestos fibres less than 5 µm were detected during examination by the more sensitive TEM technique. However, no asbestos fibres exceeding 5 µm in length were observed in either of the two background samples or the personal sample taken above the ceiling as the inspector worked. Therefore, at the times of sampling, the levels of airborne asbestos fibres in these areas were below the detection limit of these analyses. These levels are at least a factor of 2 below the Ontario Ministry of the Environment ambient asbestos guideline for continuous exposure of the general population in the outside environment. The airborne levels of asbestos in the room while the inspector worked above the ceiling were slightly higher than those observed in the other areas. However, to confirm this apparent increase, the sensitivity of these analyses would need to be improved by sampling larger volumes of air.

These results indicate that all the fibre levels (detected by PCM) were below the occupational standard in Ontario and that the asbestos fibre levels greater than 5.0 µm (detected by TEM) were in all cases lower than the guideline of the Ministry of Environment. The measured short asbestos fibre levels are obviously above background levels but the significance of this is not clear at present. The levels detected are not of a level to cause concern over occupational exposure or environmental pollution.

2.2 Maintenance Above Suspended Ceiling

This activity could be considered to be heavy maintenance or minor renovation. The work involved entering the ceiling space above a snap-in metal tile ceiling, vacuuming the surrounding tiles and removing all visible dust. This was done to prepare the area for the installation of new communication wiring above the ceiling. The work of cleaning the tiles was performed by properly trained and equipped

TABLE II

Air Monitoring Results During Maintenance or Minor Renovation above Suspended Ceiling (See notes in text)

Sample Location	Optical Microscopy (PCM) $f. mL^{-1}$	Transmission Electron Microscopy: Total Asbestos Fibres		Transmission Electron Microscopy: Asbestos Fibres >5.0 µm	
		$f. mL^{-1}$	$ng. m^{-3}$	$f. mL^{-1}$	$ng. m^{-3}$
Personal sample on worker above ceiling	0.17 [a]	370.0	6400.0	12.0	1100.0
Personal sample on Assistant	0.05	2.68 [b]	104.0 [b]	<0.07 [b]	-
Area sample close to work site	0.009 [a]	0.179	2.6	<0.02	-
Area sample distant from work site	<0.005	0.118	8.0	<0.006	-

(a) Average of two samples

(b) Approximate - see notes in text

personnel working outside normal working hours. Prior to removing any tiles an enclosure was erected and taped to the ceiling. Work practices similar to those outlined in Chapter 1 Section 5.2 were followed throughout the work.

2.2.1 Results and Discussion

The techniques of air monitoring and analysis described in Section 2.1.1 were used for this work. One worker spent most of his time above the ceiling performing the vacuuming while his assistant only occasionally entered the enclosure or the ceiling space. Both were equipped with the personal air sampling pumps. Area samples for PCM and TEM analysis were collected very close to the work site and in a distant room during the work. The results of these analyses are presented in Table II. The TEM results from the assistant are approximate as the pump stopped in the course of the work. The actual volume of air sampled was 100 to 155 litres. A volume of 100 litres has been assumed which may tend to overestimate the asbestos fibre levels. The results are presented in a similar form to those in Section 2.1.2.

The results obtained by optical microscopy (PCM) are quite low for all samples collected. The sample collected on the worker above the ceiling is the only one which shows a fibre concentration significantly above background levels. The value of 0.17 $f.mL^{-1}$ is well below the proposed Ontario occupational time weighted exposure limit for chrysotile of 1.0 $f.mL^{-1}$. The TEM results for the same worker are very high however. The levels of 370.0 $f.mL^{-1}$ or 6400.0 $ng.m^{-3}$ for fibres of all lengths or 12.0 $f.mL^{-1}$ or 1100 $ng.\ m^{-3}$ for fibres longer than 5.0 µm are at least several orders of magnitude above normal background levels.

The currently proposed Ontario occupational exposure limit for chrysotile is 1.0 $f.mL^{-1}$ averaged over 8 hours with a maximum allowable concentration of 2.5 $f.mL^{-1}$. The specified measurement technique is phase contrast microscopy (5). As discussed earlier all particles are reported which are visible in phase contrast illumination at a magnification of 450 and have lengths greater than 5 µm

and aspect ratios of 3 to 1 or greater. There is no provision for identification and only particles sufficiently wide to be observed will be reported, regardless of length. The levels proposed are based largely on experience from the asbestos processing industry where a specific distribution of fibre size exists. This distribution of fibre size may vary depending on the condition of air filtration or type of industry (4) and make a higher or lower percentage of the total fibres visible to the optical microscope. The PCM method as commonly used, is able to detect fibres only down to about 0.3 µm. Pott (3) has suggested the fibres down to 0.03 µm can have significant health effects.* Therefore, in the present case where no information on the fibre size distribution exists the PCM method may not be appropriate to determine the severity of exposure. No conclusion concerning this can be drawn on the basis of the results reported here.

The results for fibre $>$ 5.0 µm outside the enclosure or for intermittent work in the enclosure are very low in all cases (by PCM or by TEM). These indicate that the methods of enclosure and the use of the HEPA vacuum have prevented the spread of significant quantities of asbestos fibres to surrounding areas. Therefore the general building occupants appear to be protected from significant exposure to airborne asbestos fibres.

The airborne asbestos fibre concentration to which the worker is exposed however is very high as measured by TEM. Since the distribution of fibre size (ratio of visible to invisible fibres in the PCM) is not known for this type of work then this exposure may constitute a potential hazard. This hazard may not be prevented by maintaining the fibre levels within the proposed occupational levels measured by PCM. One means of ensuring that the exposure of the maintenance workers is not a potential hazard is to enforce the Ministry of Labour guidelines (8). That is, if work behind the ceiling such as that described here is necessary, then it should be preceded by removal of the asbestos.

* This size effect is an issue over which there is considerable controversy. The mention of 0.03 µm is merely meant to show one possible conclusion.

3. EFFECT OF REMOVAL PROJECT : SPRAYED MATERIAL

In order to determine the effect of asbestos removal on the detected airborne asbestos fibre levels in buildings, a number of projects were examined in detail. Visual inspection of work sites during removal of sprayed material was augmented by both optical and transmission electron microscopy before, during and after removal. A total of eight sites were monitored in this fashion. These projects included work of four contractors, four firms supplying inspectors and air monitoring services, and four firms supplying analytical services. Based on the judgement of experienced inspectors or site visits by the author, seven of the eight projects appears to be adequately performed and to exemplify adequately performed removal projects.

The remaining project, based on visual inspection by the author at the completion of the project, had been improperly performed with substantial quantities of material remaining at the completion of the work. The results of air monitoring before the start of the removal work, during removal work and after clean-up of the work site will be discussed for each project in the following sections. Where possible the results of the air monitoring will be discussed with reference to the visual inspections.

3.1 Air Monitoring and Visual Inspection

The results of the air monitoring are presented in Table III. The TEM results for projects 1, 2, 3, 4, and 8b are presented in more detail in Appendix A. Project number 8 was inspected by two different firms and the analyses were performed by two different laboratories. These inspections are described as project 8a and 8b. The optical microscopy was performed in all cases by NIOSH Method P+CAM 239 (2). The TEM analytical techniques for projects 1, 2, 3, 4, 8a, and 8b are described in Section 2.1.1. The TEM results for projects 5, 6, and 7 were obtained from air samples collected on 0.8 μm pore size cellulose mixed ester filters. These filters were then ashed and the fibres were re-suspended using a technique described elsewhere (1). There is a possibility using this technique that fibre bundles will be split up and the asbestos fibre concentration will be overestimated. Mass concentrations were not reported for these three projects or for project 8a.

TABLE III

Air Monitoring Results from Removal Projects. All Results From Area Samples. Phase Contrast Microscopy (PCM) Results Measured by NIOSH Method P & CAM 239. Individual Results and Averages Reported.

PROJECT NUMBER	BEFORE START OF PROJECT					DURING WORK OUTSIDE AREA	AFTER CONTRACT COMPLETION				
	OPTICAL MICROSCOPY	TRANSMISSION ELECTRON MICROSCOPY				OPTICAL MICROSCOPY	OPTICAL MICROSCOPY	TRANSMISSION ELECTRON MICROSCOPY			
	Fibres	Total Asbestos Fibres		Asbestos Fibres >5.0 μm		Fibres	Fibres	Total Asbestos Fibres		Asbestos Fibres >5.0 μm	
	$f.mL^{-1}$	$f.mL^{-1}$	$ng.m^{-3}$	$f.mL^{-1}$	$ng.m^{-3}$	$f.mL^{-1}$	$f.mL^{-1}$	$f.mL^{-1}$	$ng.m^{-3}$	$f.mL^{-1}$	$ng.m^{-3}$
1	0.024	0.040	2.345	<0.005	--		0.06	0.056	0.20	<0.004	--
	0.020	0.010	0.092	<0.005	--		0.04	0.062	2.05	<0.004	--
		0.011	0.044	<0.005	--		0.01	0.052	2.00	<0.005	--
		0.047	0.330	<0.005	--		0.17		0.40	<0.004	--
Average:	0.022	0.027	0.703	<0.005		(a)	0.07	0.057	1.16	<0.004	--
2	<0.1	0.024	4.53	0.003	1.4		0.1	0.027	154.2	0.002	120.0
	<0.1	0.017	2.05	0.002	1.6		0.1	0.059	64.2	0.008	53.1
	<0.1	0.019	3.14	0.004	1.8		0.1	0.075	177.3	0.013	148.0
		0.005	1.01	0.002	1.0						
Average:	<0.1	0.016	2.68	0.003	1.5	0.2[b]	0.1	0.054	131.9	0.008	107.0
3	<0.1	0.016	2.520	<0.002	--		0.1	0.028	16.5	0.002	14.0
	<0.1	0.011	1.405	0.002	0.1		<0.1	0.036	97.3	0.007	92.0
	<0.1	0.017	1.305	0.002	0.1		<0.1	0.014	60.3	0.007	60.0
Average:	<0.1	0.015	1.743	0.001	0.1	0.69[c]	<0.1	0.026	58.0	0.005	55.3
4	<0.1	0.010	1.109	0.004	0.68		<0.1	0.008	2.68	0.002	2.5
	<0.1	0.009	4.309	0.002	2.06		<0.1	0.011	0.40	<0.003	--
	<0.1	0.050	4.600	0.003	1.00			0.010	0.25	<0.003	--
Average:	<0.1	0.023	3.339	0.003	1.25	2.21[d]	<0.1	0.010	1.11	0.001	0.8
5	0.001	0.077	(e)	0.004	(e)		0.100	0.14	(e)	0.004	(e)
	0.004	0.020	(e)	<0.001	-		0.007	0.72	(e)	0.080	(e)
	0.004	0.013	(e)	0.002	(e)		0.011	0.74	(e)	<0.001	--
Average:	0.003	0.037		0.002		0.02[f]	0.039	0.53		0.028	
6	0.004	0.015	(e)	0.001	(e)		0.028	0.100	(e)	<0.001	--
	0.003	0.014	(e)	<0.001	--		0.019	0.048	(e)	<0.001	--
	0.004	0.007	(e)	0.001	(e)		0.019	0.210	(e)	0.005	(e)
Average:	0.004	0.012		0.001		0.009[g]	0.022	0.119		0.002	
7	<0.001	0.013	(e)	<0.001	(e)		0.002	0.040	(e)	<0.001	--
	0.003	0.012	(e)	<0.001	(e)		0.003	0.498	(e)	0.034	(e)
	0.002	0.024	(e)	<0.001	(e)		0.004	0.008	(e)	0.003	(e)
Average:	0.002	0.016		<0.001		0.009[h]	0.003	0.182		0.012	
8a	0.04	(e)	(e)	0.004	(e)	0.08	0.00	(e)	(e)	0.01	(e)
	0.02					0.3	0.02				
Average:	0.03			0.004		0.19	0.01			0.01	
8b	<0.01	0.019	0.13	<0.004	--	0.04		0.172	1301.1	0.024	1200.0
						0.09		0.340	22.9	<0.006	--
Average:	<0.01	0.019	0.13	<0.004	--	0.07	0.03[i]	0.256	662.0	0.012	600.0

Code

(a) No samples taken
(b) Average of 6 measurements ranging from <0.1 to 0.4 $f.mL^{-1}$
(c) Average of 9 measurements ranging from <0.1 to 2.8 $f.mL^{-1}$
(d) Average of 7 measurements ranging from 0.1 to 8.7 $f.mL^{-1}$
(e) Figure not reported
(f) Average of 7 measurements ranging from 0.006 to 0.039 $f.mL^{-1}$
(g) Average of 8 measurements ranging from 0.006 to 0.013 $f.mL^{-1}$
(h) Average of 12 measruements ranging from 0.002 to 0.16 $f.mL^{-1}$
(i) Average of 5 measurements ranging from 0.01 to 0.09 $f.mL^{-1}$

Projects 1, 5, 6, and 7 involved the removal of chrysotile - containing fireproofing above suspended ceilings. Projects 2, 3, 4, and 8 involved removing amosite-containing fireproofing above suspended ceilings or exposed in service rooms. The projects will be discussed separately based on written comments made by the inspectors. The comments, of course, will concentrate on any problems that were encountered by the inspector.

Project 1 was a very well performed project in a relatively new building. There were no unexpected problems encountered in the work. The clean-up procedure used by this contractor was not the usual multiple vacuuming and wet cleaning used in most work (see Chapter 1). Instead a latex adhesive (POLYCO 804™, Borden Chemical Co.) was sprayed on all surfaces after the first thorough cleaning step and before re-fireproofing (6). This was intended to increase the deposition rate of the fibres and to bind the fibres in a film of the sealant. The building was returned to service on the basis of a visual inspection. The air samples after contract completion were taken after the building was back in normal use. Projects 2, 3, and 4 were performed by one experienced contractor and inspected by one individual. In each case air monitoring was performed at the completion of the second clean-up after visual inspection. Project 2 was run by an experienced foreman and the inspector reported no problems on the project. The workers on project 3 were less experienced and some problems of contamination of surrounding areas were encountered during the work. There were also some problems of over-wetting on project 3. Project 4 was performed in a rather sloppy manner. The workers initially were not adequately trained in the use of and need for correct enclosure and decontamination procedures. Contaminated equipment and some lumps of asbestos were left outside the work area and a clean-up was necessary to correct this problem. In spite of the problems encountered in the course of these three projects, the completed work was judged to be quite acceptable based on a visual inspection.

Project 5 was performed with a slight negative pressure in the work area. This was produced by a truck mounted vacuum system which drew air from a single location inside the rather large work site, filtered it, and expelled it outside the work area. The job was apparently well performed. Occupational air monitoring was performed on this project. The airborne fibre levels on personal samples in the work area averaged 1.08 $f.mL^{-1}$, with a range from 0.00 to 10.87 $f.mL^{-1}$. Projects 6 and 7 were performed by the same contractor as project 1. The work was inspected by the same individual who had inspected project 5. The inspector indicated that the work was adequately performed but that unlike project 5 no negative pressure was used in the work sites. Occupational air monitoring on the asbestos removal workers on project 6 showed on average fibre concentration of 0.30 $f.mL^{-1}$, with a range of 0.16 to 0.93 $f.mL^{-1}$. The occupational monitoring results on project 7 averaged 0.33 $f.mL^{-1}$, with a range from 0.11 to 0.62 $f.mL^{-1}$. The clean-up procedure used by this contractor was the same as used on project 1. In this case the sealer was a copolymer asbestos sealant (MULCO PROTECKTOR^{TM} from Double A/D Distriburors Ltd.,) (6). It was also aprayed on all surfaces after the first thorough cleaning step and before the final cleaning.

Project 8 was monitored by two separate firms. The results reported as 8a were obtained by the firm employed by the building owner. This firm was responsible for ensuring correct contract performance and had an inspector in attendance virtually every working day. The firm was quite inexperienced in inspecting and controlling asbestos abatement work. There were no severe problems reported to the building owner by this firm. Occupational monitoring on the work site indicated an average fibre concentration of 3.34 $f.mL^{-1}$, with a range of 1.2 to 6.08 $f.mL^{-1}$. Air sampling in the finished work area was performed by this firm very soon after completion of the work. The second inspection and air monitoring (reported as 8b) were provided by the author. This inspection was merely intended to provide a comparison of the results of two separate inspection and monitoring firms. The author had no direct contact with the contractor in the sense of recommending changes in work practices or equipment. This second inspection indicated that the clean-up had been entirely inadequate and that substantial quantities of unsealed amosite had been left in the work area. This final inspection and air sampling was performed several months after the building had been returned

to normal use.

3.2 Discussion

3.2.1 Before Start of Project

The results of air monitoring before the removal of any asbestos-containing material are shown in Table III. The results from the optical microscope (phase contrast microscopy, PCM) in all cases are below 0.1 $f.mL^{-1}$ which is generally accepted as the lower limit of reliable quantitation of this method. The very low levels reported are typical of normal background PCM levels. The buildings can not however be considered asbestos workplaces and therefore comparison with the existing occupational levels measured by PCM is inappropriate.

As discussed in Section 2 the Ministry of the Environment applies a guideline of 0.04 $f.mL^{-1}$ (fibres longer than 5 μm measured by TEM) for control of asbestos fibre concentrations in the outside atmosphere to which the general public may be exposed continuously. In the eight removal projects monitored before removal the highest concentration of asbestos fibres greater than 5.0 μm in length was 0.004, a factor of 10 below this guideline. The maximum mass concentration reported was 1.5 $ng.m^{-3}$ of fibres longer than 5.0 μm. Low levels of short asbestos fibres (less than 5.0 μm in length) were detected in each of the samples (except for 8a where the result was not reported). In every case however the detected fibre or mass concentration of these fibres is very low (less than 0.04 $f.mL^{-1}$ or 4 $ng.m^{-3}$). Low levels of short chrysotile fibres are normally present in the outside environment. In addition, a few small asbestos fibres, both chrysotile and amphibole, are frequently detected as a result of the known low level contamination of the unused air sample filters.

The levels reported here are not such as to indicate a significantly elevated airborne fibre level prior to the asbestos removal. The results of Section 2.2 indicate the very elevated asbestos fibre levels which can occur if friable asbestos containing materials are disturbed by maintenance or renovation. In the eight buildings reported here the samples were taken while the building was in normal use but not during any

heavy maintenance or renovation work. The results of the air monitoring are representative only of the airborne asbestos fibre levels at the time of sample collection and should not be used as a basis for the selection of the appropriate control measure. This is discussed in more detail in Chapters 1 and 7.

3.2.2 During Removal

3.2.2.1 Outside the Work Area

The airborne fibre concentrations were measured by PCM outside the work area during work in all projects except number 1. The concentrations outside the work area on projects 3 and 4 were on average above the proposed occupational standard of 0.5 $f.mL^{-1}$ for amosite. In addition, the measured fibre levels in the remaining amosite jobs (projects 2 and 8) were in all cases higher than the projects involving chrysotile removal (projects 1, 5, 6 and 7). This is consistent with the observation that the generation of dust is more severe during amosite removal than during chrysotile removal. The enclosures were sufficient to maintain fibre levels outside the work area below occupational standards in all projects except 3 and 4 whether negative pressure was used or not. The effect of negative pressure in the work site on fibre levels outside the site cannot be adequately evaluated based on the limited information in Table III. The comments of the inspector reported in Section 3.1 and the results in Table III indicate that airborne fibre concentrations outside the work area can easily exceed occupational levels if the isolation rooms are not maintained, the decontamination areas are improperly used or asbestos contaminated equipment is placed outside the work area. This demonstrates the need for adequate inspection of the enclosures and work practices throughout the project.

Airborne asbestos fibre concentrations outside the work area were measured by TEM on project 8b. The single sample analyzed gave the following results for total asbestos fibres: 0.32 $f.mL^{-1}$, 1301.1 $ng.m^{-3}$; and the following results for fibres longer than 5.0 μm: 0.058 $f.mL^{-1}$, 991.0 $ng.m^{-3}$

These levels are very much higher than the concentrations reported in Table III before work commenced. The levels for fibres longer than 5.0 µm exceed the Ministry of Environment guideline of 0.04 $f.mL^{-1}$. This result confirms that asbestos fibres are being allowed to contaminate the surrounding area. This confirms the contamination suggested by the PCM results. The evaluation of this contamination of the surrounding areas must consider that the duration of the work was rather short (less than one month). The Ministry of Environment guideline of 0.04 $f.mL^{-1}$ is intended for long-term or continuous environmental exposure.

3.2.2.2 Inside the Work Area

Occupational monitoring of the asbestos removal workers was performed only on projects 5,6,7, and 8. The results of the occupational monitoring are summarized below.

TABLE IV

OCCUPATIONAL EXPOSURES DURING REMOVAL
(NIOSH METHOD P+ CAM 239)

PROJECT Number	Number of Samples	Average fibre level $f.mL^{-1}$	Range $f.mL^{-1}$
5	18	1.08	0.00 - 10.87
6	16	0.30	0.16 - 0.93
7	19	0.33	0.11 - 0.62
8	5	3.34	1.20 - 6.08

Projects 5,6, and 7 involved the removal of a chrysotile-containing material while project 8 involved amosite removal. Project 5 employed a truck mounted system to provide negative pressure in the work site. The results from projects 6 and 7 indicate that these jobs, both performed by the same contractor, were performed with excellent control of airborne fibre levels in the work site. Project 5 showed a significantly higher average fibre level in the work site, although fibre concentrations measured in project 5 were all below 1.0 f/cc except for the results on one worker. The high levels on this worker confirmed obvious careless work habits on his part. The worker was transferred at this time to a different job in the work area and this solved the problem of elevated fibre levels. The average fibre concentration excluding this one worker was 0.34 $f.mL^{-1}$ which is very similar to projects 6 and 7. The use of

negative pressure has been shown on other projects to reduce fibre levels in the work area (7). It also provides additional security in the event of a breach in the enclosure.

Project 8, which involved amosite removal, consistently showed the highest fibre concentration in the work site. All of the five samples collected were above 1.0 $f.mL^{-1}$. The proposed Ontario Regulations (5) specify that powered air purifying positive pressure dust respirators or positive-pressure supplied air respirators must be used if the level of 1.0 $f.mL^{-1}$ is exceeded in an area where amosite fibre is present. The inspector apparently made no recommendation to this effect and the workers used the replaceable filter-type half-face air purifying dust respirator which is not acceptable at these fibre levels.

Although no occupational monitoring in the work site was performed on the other projects the levels obtain by PCM outside the work site do give some cause for concern in projects 3 and 4. The average levels of 0.69 and 2.2 $f.mL^{-1}$ outside the work site (which are above the proposed amosite occupational standard) imply clearly that the levels inside the work area are also above the level of 1.0 $f.mL^{-1}$. In neither of these projects was the contractor urged to provide an increased level of respiratory protection. There was no provision in the job specifications for occupational monitoring to determine the fibre concentration inside the work area. No on-site inspection was provided by the Ministry of Labour or other responsible authority to investigate the occupational exposure of the workers.

3.2.3 After Completion of Project

3.2.3.1 Adequately Performed Projects

The eight projects listed in Table III were all monitored by PCM and TEM at the completion of work. The results reported for projects 1 and 8b were obtained several months after the completion of the work when the building was back in normal use. All remaining results were obtained shortly after completion of the final clean-up and before the work area was returned to the owner.

As discussed earlier, projects 1 through 7 were judged to be adequately performed and the completed job was judged to be acceptable to the inspector. The PCM results on projects 1 through 7 are equal to or lower in all cases than 0.1 $f.mL^{-1}$ which is quoted as the limit of reliable quantitation for the PCM method (2). The limitations of the PCM method discussed earlier are such that TEM monitoring must be used to provide accurate information on airborne asbestos fibre concentrations in this environment.

The results of the TEM monitoring after contract completion, presented in Table III, generally indicate that the airborne asbestos fibre levels are quite low in all seven cases. Considering only fibres longer than 5.0 μm the highest fibre concentration is 0.028 $f.mL^{-1}$ which is well below the Ministry of Environment guideline of 0.04 $f.mL^{-1}$. The mass concentration, where reported, ranges from 0.0 (no fibres detected) to 107.0 ng m^{-3}. The total asbestos fibre concentrations (fibres of all lengths) range from 0.026 to 0.53 $f.mL^{-1}$ and 1.11 to 131.9 $ng.m^{-3}$. These TEM results after the completion of the contract are higher than levels detected before the start of the project in all cases except project 4. The concentrations are in all cases well below the environmental guideline. Since the TEM sample is generally collected immediately after the second clean-up it is expected that these levels would decrease when the area is opened and the low concentration of remaining fibres are dissipated to the surrounding areas or vented to the outside of the building. The TEM results therefore appear to agree with the acceptable visual condition of the work areas.

No correlation is apparent between work practices during removal and measured TEM fibre levels after the work is completed. For example the TEM concentrations after contract completion for project 2 are greater than for project 3 which in turn are greater than for project 4. The inspector on these jobs indicated that the greatest difficulties and highest fibre levels during removal were measured on project 4 with project 2 posing the least difficulty. Therefore, the measured asbestos fibre concentrations at the completion of the project are opposite to the levels anticipated from consideration of the work practices on these projects.

3.2.3.2 Inadequately Performed Project

Although project 8 was approved by the inspection firm employed by the building owner a later inspection by the author (confirmed by the building owner) indicated that the project had not been satisfactorily completed. Significant quantities of unsealed amosite could be found on equipment, floors,and ducts. This was severe enough to require a complete re-cleaning of the area at a later time. The air monitoring results obtained at the time of the later inspection and reported as 8b were obtained before this delayed cleaning step.

The PCM levels at the completion of project 8 were determined to be low by both the inspection firm immediately after the second clean-up and by the author after the building was returned to use. The fibre concentrations by PCM are similar to those measured before the start of the project. The PCM method is clearly not adequate to be used on its own as a measure of satisfactory contract performance.

The asbestos fibre concentrations by TEM were reported only for fibres longer than 5.0 μm by the first inspection firm. The level of 0.01 $f.mL^{-1}$ agrees closely with the level measured at the time of the second inspection after the building was back in service (0.012 $f.mL^{-1}$). The value of 0.012 $f.mL^{-1}$ must be treated with caution as it is the average of two results only. One of the samples contained no fibre of length greater than 5.0 μm while the other sample gave a value of 0.024 $f.mL^{-1}$. The full results of the second TEM air monitoring appear to more clearly indicate the inadequate project performance. The average concentration of asbestos fibres of all lengths was 0.256 $f.mL^{-1}$ or 662.0 $ng.m^{-3}$. The concentration of asbestos fibres greater than 5.0 μm in length was 0.012 $f.mL^{-1}$ or 600.0 $ng.m^{-3}$. These results are significantly higher than concentrations detected before the start of the project and if the analytical results of the first inspection had been reported in full (rather than just 0.1 $f.mL^{-1}$ for fibres longer than 5.0 μm) they might have indicated a potential problem in contract performance. The mass concentrations in particular appear to indicate a potential problem as the mass concentration of 600.0 $ng. m^{-3}$ is more than 5 times greater than projects 1, 2, 3, and 4 where the mass concentrations are reported.

The TEM analyses of projects 5, 6, and 7 also did not include the mass concentrations of the asbestos fibres. The results of the TEM monitoring on project 8 indicate that the mass concentrations may be a more sensitive measure of the effectiveness of the clean-up than fibre concentration. The concentration of total asbestos fibres in project 5 (0.53 f.mL-1)is more than double the total asbestos fibre concentration measured in project 8b (0.256 f.mL-1). The mass concentration, if it had been reported, may have indicated a correspondingly high mass concentration due to contamination not detected by the inspection. It appears from these results that TEM monitoring may be of some use in supplementing visual inspection of a removal project.

4. EFFECT OF REMOVAL PROJECT : PIPE AND BOILER INSULATION

One project involving the removal of approximately 1,400 square metres of boiler and pipe insulation was also monitored. The block or board type insulation contained both amosite and chrysotile. It was applied in a number of layers to a total thickness of up to 4". Each block was wired or strapped into position and the entire unit was coated with mesh, asbestos-cement or asbestos-free cement, and paint. The installation was in excellent condition and was removed only because the equipment was being dismantled. The project was monitored from before any material was removed until the completion of the clean-up.

The removal of asbestos-containing pipe and boiler insulation has generally been performed in Ontario without asbestos-related precautions. The contractor, building owner and the author (who inspected the work) therefore had to develop appropriate work practices as this work progressed. The initial work practices were typical of those used in the removal of sprayed material. The removal of the pipe insulation was much more difficult, however, and the contractor and inspector devised alternate work practices. These modified work practices maintained the airborne fibre levels within concentrations appropriate for the respiratory protection provided to the workers. The results of visual observations and air monitoring of these two types of work practices will be discussed in this section.

4.1 Air Monitoring and Visual Inspection

The methods of sample collection and analysis used in this project have been previously described in Section 2.1.1. In the present project significant levels of non-asbestos fibres and non-fibrous dust were present both inside and outside the work area and short sampling times were used to collect the samples for analysis. The results of the PCM and TEM air monitoring before the asbestos removal started and after the work area had been cleaned are reported in Table V. The TEM results are presented in more detail in Appendix K. The occupational (PCM) monitoring during removal will be discussed below.

At the start of the project the contractor applied the techniques appropriate for the removal of sprayed material. These precautions included the use of asbestos-approved half-face respirators, protective clothing and showers for the workers and the enclosure of the work area with plastic. An attempt to wet the material with amended water was made but the multiple layers of insulation made adequate wetting impossible. The initial methods of asbestos block insulation removal were similar to methods used until recently in all asbestos insulation block removal. The outer layers of paint and cement were broken with a hatchet or hammer, the material was wetted if convenient and dropped to the floor where it remained for some time until placed in bags or barrels and removed from the work site. Occupational air samples taken during this initial work indicated that the fibre levels by PCM were too high to count. The airborne fibre concentration was well in excess of 5.0 f.mL-1 and may have been of the order of 10.0 f.mL-1 or more.

Work on the removal was stopped as soon as these work practices were observed by the author during the first site inspection. This shut-down occurred even before the PCM samples had been analyzed. Modified work practices were established during this shut-down in consultation with the workers and the contractor. The procedure included:

(a) men working in two-man crews with one equipped with a water spray at all times;
(b) immediate bagging of the blocks before they are allowed to fall to the floor;
(c) removal of the insulation in layers with wetting of each layer as it is being removed;
(d) provision of better water spray equipment;
(e) better control of bagged waste.

These procedures slowed the rate of removal work significantly. It was anticipated that the modified techniques would reduce the airborne fibre

TABLE V

Air Monitoring Results Before and After Removal of Asbestos Insulation Block

(Optical Microscope Results Determined by NIOSH Method P + CAM 239)

Time of Sample	Optical Microscopy (PCM)	Transmission Electron Microscopy: Total Asbestos Fibres		Transmission Electron Microscopy: Asbestos Fibres >5.0 µm	
	$f.mL^{-1}$	$f.mL^{-1}$	$ng.\ m^{-3}$	$f.mL^{-1}$	$ng.\ m^{-3}$
Before removal	0.11	1.274	1440.0	0.084	1270.0
	0.12	0.536	61.0	0.012	30.2
	0.87				
	0.38				
Average	0.37	0.905	750.5	0.048	650.1
After Clean-up	0.58	1.85	920.0	0.146	745.0
	0.66	1.62	3317.0	0.096	1306.0
	0.39				
	0.45				
	0.26				
Average	0.47	1.74	2118.5	0.121	1025.5

concentration to a level at which powered air purifying respirators would not be required. The use of these powered air purifying respirators was extremely difficult in the confined work area and it was felt that the more compact non-powered masks were safer for the workers in other respects. Once these modified procedures were in use the air monitoring was repeated. The average measured fibre level by PCM was 4.9 f.mL-1, with a range of 3.8 to 6.1 f.mL-1. Although these fibre levels indicated a significant improvement in the conditions, the levels were still higher than anticipated. Based on this result all the workers were equipped with the powered air purifying respirators which provided adequate respiratory protection to comply with the proposed Ontario Regulations and Code for Respiratory Equipment for Asbestos (5).

The workers became more proficient and rapid using these new procedures as the work progressed. In addition to this, the work methods improved and the fibre levels decreased. Air monitoring results near the end of the project gave an average fibre concentration of 1.0 f.mL-1, with a range from 0.77 to 1.3 f.mL-1. This clearly indicated that the experience gained by the workers on this project resulted in significantly improved work practices and fibre levels.

Monitoring outside the work site was also performed while the removal work was progressing. The PCM results averaged 0.43 f.mL-1, with a range from 0.1 to 1.1 f.mL-1 during the course of the work.

4.2 Discussion

The results of the air monitoring shown in Table IV and presented in the previous section are difficult to interpret for several reasons. The PCM samples obtained before the start of the project showed fibre levels well above usual background readings. Examination of these fibres with the electron microscope indicated that a large fraction, likely a majority, of these fibres were non-asbestos. These non-asbestos fibres were associated with materials commonly in use in the building. This result indicates that the PCM results outside the work area itself are somewhat suspect.

The TEM results before the work started did show the presence of asbestos fibres, largely amosite. The concentration of asbestos fibres

longer than 5.0 μm was 0.048 $f.mL^{-1}$ or 650.1 $ng.m^{-3}$. This level is above the Ministry of Environment guideline of 0.04 $f.mL^{-1}$ for control of asbestos fibre concentrations in the outside atmosphere to which the general public might be exposed continuously. Considering that the TEM reports only asbestos fibres and that the method will detect fibres not visible in the optical microscope the actual asbestos fibre levels are very much below the proposed occupational standard in Ontario (at least a factor of 10 below this standard). No source of these fibres could be identified by the author or the building owner. Currently further work is ongoing to identify and eliminate this source of contamination.

The TEM fibre concentrations after completion of the block removal and clean-up are elevated from the TEM levels detected before the removal was started. The fibre concentrations of 0.121 $f.mL^{-1}$ or 1025.5 $ng.m^{-3}$ could not be conclusively attribted to the removal of the asbestos-containing block since the levels prior to the removal were also much higher than normal background levels. Visual inspection of the completed project indicated that the removal and clean-up had in fact been adequately performed. No conclusion can be drawn concerning the effect of the removal of the asbestos-containing block on the airborne fibre levels in the building other than to point out the apparent increase in measured asbestos fibre levels in this limited number of samples. More block insulation removal projects would have to be monitored before a conclusion could be drawn.

The results of the occupational monitoring indicate that the removal of asbestos-containing insulation block can produce airborne fibre levels far in excess of the proposed Ontario Regulations. The control of fibre levels proved to be much more difficult than in the removal of sprayed asbestos-containing material due to the difficulty of wetting the material. The contractor's performance in this case improved sufficiently to suggest that acceptable work practices could be adopted to protect the workers.

5. CONCLUSIONS

The results of the inspection and maintenance behind suspended ceilings hiding sprayed asbestos indicated that the control option of management and custodial control described in Chapter 1 may not be appropriate in some buildings due to maintenance activities in the building. The air monitoring of the brief inspection above the suspended ceiling indicated that the inspector or persons in the vicinity were exposed to low fibre concentrations (by PCM) or asbestos fibre concentrations (by TEM). There was no apparent effect on asbestos fibre levels elsewhere in the building. The air monitoring during the cleaning of tiles prior to the installation of wiring showed only slightly elevated fibre levels (by PCM) for the workers. However the TEM revealed the extremely high asbestos fibre concentrations to which the worker above the ceiling was exposed. These fibres are too thin to be observed in the optical microscope and are not normally considered in occupational monitoring by PCM. In any building where a programme of management and custodial control is proposed, consideration must be given to the maintenance or minor renovations which may occur in the building. If the reported exposure to fibres too thin to be detected by PCM are thought to present a significant health hazard, and maintenance procedures similar to the tile cleaning and removal are performed regularly, then this option is likely inappropriate unless more stringent work practices are developed.

The results of the monitoring of the eight projects to remove sprayed asbestos indicate that asbestos removal can be performed in such a fashion as to completely remove the asbestos-containing material, protect the workers and leave the building with very low fibre levels. One project clearly showed that improperly performed removal work can result in a greater potential contamination of the building than if the material had been left undisturbed. The results of the parallel inspections of this one inadequate project indicate the necessity of an experienced inspector to oversee the correct job performance and particularly the final clean-up.

Air monitoring results, both PCM and TEM, before the start of the work could not be used as a basis on which to select the appropriate control option. The measured fibre levels (by PCM) or asbestos fibre levels (by TEM) were very low in all buildings prior to the start of the project.

PCM monitoring during the removal outside the work area proved to be useful in several instances in confirming sloppy work practices reported by the inspector. Visual inspection of the work site proved to be the most useful method of overseeing the removal work. The results of the occupational (PCM) air monitoring indicate that powered air-purifying respirators were necessary on at least 3 of the 4 projects involving amosite removal to remain within the proposed Ontario Code for Respiratory Equipment for Asbestos. This has not in the past been enforced by building owners nor the Ministry of Labour. There is no sign that this situation is changing at present.

Air monitoring by PCM at the completion of work was not useful in determining whether the removal of the asbestos and clean-up of the area had been performed satisfactorily. TEM air monitoring appeared to give some indication of the effectiveness of the removal and clean-up, This appeared to be particularly the case with TEM analysis of total asbestos fibres (all lengths) and with the mass concentration of asbestos fibres. The data in this section are too limited to permit this to be conclusively demonstrated. In general the measured asbestos fibre levels or mass concentrations are higher at the completion of the asbestos removal but still very much lower than the Ministry of the Environment guideline for airborne asbestos fibre. Visual inspection appears to be the necessary part of ensuring that all asbestos-containing material has been removed and the work area properly cleaned; air monitoring may or may not provide a useful supplement to this visual inspection.

The inspection and occupational air monitoring results of the asbestos-containing insulation block removal illustrated the problems which may be encountered in this type of asbestos removal work. The airborne fibre levels were generally higher than in the removal of sprayed asbestos-containing materials. Specialized work practices can reduce the fibre levels, but powered air purifying respirators must be used to comply with the proposed Code for Respiratory Equipment for Asbestos until the workers gain necessary experience.

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CHAPTER 8

CONCLUDING OBSERVATIONS AND RECOMMENDATIONS

1. INTRODUCTION

The work performed for the Royal Commission on Asbestos by the author has been reported in the previous seven chapters. The purpose of this final chapter is to recapitulate some of the more important conclusions drawn in each of the previous seven chapters and to consider the subject of asbestos in buildings in its entirety. The format of this chapter is different from that of the previous chapters which were structured to present the data collected in the study. This chapter is intended to provide general guidance to the reader based on the data collected and the judgement of the author. This is done by posing and answering a series of questions on the subject of asbestos in Ontario buildings. In order to keep this chapter as concise as possible the conclusions of the previous seven chapters are not re-stated in their entirety and the reader should refer to those chapters as well.

2. CONCLUSION AND RECOMMENDATIONS

Question 1: What materials in buildings have the potential of producing a level of airborne asbestos significantly above ambient levels?

Response 1: Any friable products which contain asbestos and are used in buildings have a potential of producing airborne asbestos fibres. This does not however mean that these products in a building do necessarily produce airborne asbestos levels significantly above ambient levels. This has been confirmed by air sampling and electron microscope analysis from other jurisdictions reported in Chapter 1 or from Ontario buildings reported in Chapter 6. However when these friable asbestos-containing materials are disturbed the potential clearly exists for the production of airborne asbestos fibre levels well above ambient levels and in some cases for the production of airborne fibre levels well above the proposed Ontario occupational standards for asbestos.

Question 2: When are significantly elevated levels of asbestos fibres released from this potential source of contamination?

Response 2: When friable asbestos-containing materials are disturbed by physical contact asbestos fibres are released to the air. This disturbance may be caused by maintenance work near the friable material or above a suspended ceiling hiding friable material, by renovations which affect the friable material, or by demolition of a building or structure containing friable material. The extent of disturbance necessary to produce a specific level of airborne asbestos fibres depends on a number of factors. A major factor is the friability of the material being disturbed. Obviously a low density dry applied (fibrous) spray with a high asbestos content and a low binder content will more easily produce elevated airborne asbestos levels than a higher density wet applied (cementitious) spray with a lower asbestos content. The air monitoring results in Chapters 1 and 7 give some indication of work which will produce significantly elevated fibre levels. Thus brief inspections above a suspended ceiling hiding friable asbestos fireproofing do not appear to produce levels above current occupational standards for the worker or above current environmental standards in the building. Other work which requires extensive disturbance of ceiling tile, direct contact with friable materials, or the removal of even small quantities of friable material can produce levels above both the occupational and environmental standards. No absolutely definitive rules can be established to differentiate between the activities which produce these levels. In some cases airborne fibre levels significantly above ambient levels can also be produced by routine cleaning activities which disturb any settled asbestos fibre.

There is currently some debate on whether there is fibre release from asbestos coated fire dampers or from asbestos-containing ceiling tile during normal use or removal. The author recommends that a study dealing with the release of asbestos fibres from these materials be performed and a statement concerning the need for any abatement action be made. Until that time the author recommends that no action be taken to replace or encapsulate these tiles or dampers beyond normal building maintenance activities.

Question 3: How can a potential hazard be identified and what would the total cost be to Ontario building owners?

Response 3: As discussed above, any friable asbestos product constitutes a potential hazard of significantly elevated fibre levels. This potential hazard can become an active problem if the material is disturbed by some maintenance activities, renovation, or demolition of the building. The only way to identify every potential hazard would be to inspect every building which could conceivably contain a friable asbestos product, sample all friable materials and have the materials analyzed. This would constitute a major undertaking and be extremely costly and time consuming. The cost of a preliminary inspection for sprayed materials has been estimated in Chapter 4 to be in the order of $0.04 per square metre. If one assumes that a total area of 45,000,000 m2 of industrial, commercial, institutional, and governmental construction in Ontario (1950 - 1973) were to be inspected the total cost of this identification would be $1,800,000.00. This assumes quite properly that virtually no sprayed material is located in residential construction. It is not generally possible to isolate and inspect only buildings constructed or renovated during these years (1950 - 1973) and in practice a very much larger area of buildings would have to be inspected for sprayed material. The cost could therefore be several times greater than the above estimate. These numbers include only inspection for sprayed material, not other forms of friable asbestos (most notably pipe and boiler insulation). Since these materials were used in all types of construction (including some residential construction) over a large period of time the cost of inspection for these materials would be expected to be greater than for sprayed material. One problem of a universal inspection programme is that once any friable asbestos product is identified in a building, whether it is releasing fibre to the building or not, public or worker concern is aroused. Because of this concern abatement projects may be performed where there is no immediate risk of fibre release.

No correlation was found between the measured fibre levels in the Ontario buildings monitored and any of the three hazard assessment indices tested. There indices generally depend on visual inspection and bulk material analysis. A similar result has been recently reported by the EPA in evaluating their own exposure assessment algorithm. These hazard indices at best appear to measure the potential ease with which fibres may be released from a surface-- not to evaluate any actual hazard. A much more important factor in the judgement of the author is the amount of disturbance to which an asbestos-containing friable material will be subject.

Since friable asbestos-containing materials do not apparently produce significantly elevated fibre levels when in an undisturbed condition a second method of preventing exposure of workers to elevated fibre levels is also possible. This method would require the analysis of any friable material which would be disturbed by substantial maintenance work, renovation, or demolition activity, and the use of appropriate asbestos control measures only at that time. The inspection must include work which involves major disturbance of a suspended ceiling hiding friable sprayed asbestos. This is similar to the recommendation contained in the Ontario Ministry of Labour "Guideline for the removal and treatment of asbestos on construction projects." This method of protecting workers from exposure to elevated asbestos fibre levels would be much less expensive than immediate universal inspection and could extend the asbestos abatement work over a longer period of time.

There are some major drawbacks to this approach however. Firstly the exposure of maintenance workers to asbestos would be difficult to control since the work they perform would not normally be considered either renovation or demolition. Secondly, there is no guarantee that all firms involved in renovation or demolition work will indeed comply with the requirement for sampling and analysis of friable materials. At the present time only projects in excess of $50,000.00 need be reported to the Ministry of Labour for mandatory inspection. The author is personally aware of numerous projects costing less than $50,000.00 which should fall under the Ministry of Labour Guidelines for asbestos on construction projects and which have been performed without following these guidelines. This is partially due to the fact that many of the contracting firms are not aware of the presence of friable materials containing asbestos, are unaware of the correct procedures to be followed, or are incapable of carrying out these procedures. Therefore the contractor, who would normally be the party responsible for notifying the Ministry and enforcing the rules to protect his own workers, is being asked in many cases to close down the contractor's own project. This is obviously an unworkable procedure. It is the author's opinion that the building owner should also be made legally responsible for ensuring that friable materials are analyzed prior to disturbance by renovation or demolition. This sampling may be performed by either Ministry of Labour inspectors or inspectors from the private sector. This second inspection method is therefore subject to much greater problems of enforcement than the universal inspection programme but, if properly applied, could be as effective. A higher degree of worker awareness of the potential hazard of airborne asbestos during renovation or demolition would aid the enforcement of this regulation.

Question 4: What constitutes an appropriate asbestos control programme?

Response 4: Removal of all friable asbestos containing material from a building constitutes the only truly permanent solution to the potential for the release of airborne asbestos during the normal use and maintenance activity, renovation or demolition of a building. As long as the friable material is left in an undisturbed condition, however, a programme of management and custodial controls may avoid significant worker exposure to elevated fibre levels in many buildings. If a management and custodial control programme (referred to as "deferred action" by the U.S. Environmental Protection Agency) is adopted a number of conditions must be assured. These conditions include: ensuring that routine maintenance is such that the friable material is not extensively disturbed, ensuring that renovations or demolition will be properly performed following correct procedures for asbestos-related work, notifying all persons who may disturb the material in their duties, training those staff in the correct procedures of maintenance or cleaning near the friable materials, and ensuring that periodic re-inspection be performed to guarantee that the above procedures are being followed. There are some situations in which a management and custodial control programme is not appropriate because compliance with the above steps cannot be assured or because high fibre levels are produced during routine maintenance. The steps of a management and custodial control programme are described more fully in Chapter 1, Section 5. This method is particularly appropriate in buildings containing friable pipe and boiler insulation. This material is usually already coated with cloth and paint and need only be removed when other building alterations or demolition require the removal or alteration of the piping or boiler itself. Any damage to the covering should be repaired and future damage avoided.

It is the author's judgement that neither encapsulation nor enclosure are generally useful asbestos control procedures with only a few exceptions. These exceptions will be discussed below. Neither of the methods will prevent the generation of airborne asbestos when the solid enclosure is breached or the layer of sealer or encapsulant is damaged. This means that at the time of extensive renovation or demolition of the building the asbestos must be removed following the appropriate procedures. In addition

once a friable sprayed material is enclosed or encapsulated the later removal of the material is made more difficult. As pointed out in Chapter 2, Section 4, the EPA has indicated that encapsulation can not be effectively performed at all on many types of sprayed friable materials. As discussed above, friable materials, unless disturbed as would be the case during encapsulation or enclosure, do not apparently release significantly elevated levels of airborne asbestos fibre. Therefore in general, enclosure or encapsulation are neither necessary in the short-term to prevent fibre release during normal building use nor effective in the long-term in preventing fibre release during extensive renovation or demolition. The use of encapsulation, as a less expensive control measure than removal, is occasionally used merely to calm employee or parental concerns. This is a use which is known to the author but the potential for elevated fibre levels during the work and the possibility of later disturbance of the material make this generally inappropriate in the author's judgement.

Encapsulation or enclosures are appropriate, however, in some specific cases. The repair of pipe or boiler insulation usually involves some enclosure or encapsulation. An encapsulant or enclosure can be used in some local areas that are impossible to access during asbestos removal work. Encapsulants or sealers are commonly used after asbestos removal to "seal down" any loose fibres which may have been missed by the removal or cleaning procedures. This is particularly the case on concrete decks or on the overspray of the asbestos-containing materials which is often found on walls above the suspended ceiling. If tiles are being re-used after asbestos removal these tiles are usually cleaned and the top surface is often coated with a layer of paint or encapsulant to seal any residual asbestos-containing dust. In some cases where asbestos removal is absolutely impossible, encapsulation or enclosure may be appropriate. The building owner should be aware that this action does not in general permanently resolve the potential problem. In a few instances a penetrating sealer can saturate the entire thickness of some acoustic products and render the entire mass non-friable. In this limited use the encapsulant could be considered a permanent solution.

Question 5: What is the effectiveness of these control programmes?

Response 5: When correctly performed in an appropriate situation both management and custodial control and complete removal of friable asbestos-containing materials can be effective asbestos abatement techniques. As the limited air monitoring of maintenance-type activity in Chapter 7 showed, the release of fibres to the building environment can be controlled in some instances by the use of special equipment, work practices, and enclosures. A programme of management and custodial control is not appropriate in other cases where it is not certain that these procedures will be followed by maintenance staff, other building occupants or outside workers (telecommunications workers, etc.), or where the release of high fibre levels will occur on a routine basis due to necessary building operations. Air sampling may be useful in determining whether maintenance activities can be performed without exposing the worker or other building occupants to elevated asbestos fibre levels during these maintenance operations.

The removal of friable material from the building can be the most effective permanent control procedure if it is performed correctly. The air monitoring results and visual inspections indicate that removal work can be performed in one area of a building without the need to close the building or isolate neighbouring areas if care is taken in erection of the work enclosure. As shown in Chapter 7 the airborne asbestos fibre levels immediately after removal of sprayed material are similar to or somewhat higher than the levels detected before the removal started. These slightly elevated levels are still well below the Ministry of Environment guideline of 0.04 fibres per millilitre and would be expected to decrease sharply once any air exchange occurs when the work area is returned to normal use. It is essential that the work be correctly performed however. Project 8 in Chapter 7 is an example of the potential problems which may be caused by an inadequate removal job. At the completion of this project the optical microscope detected 0.01 fibres per milliltre and the transmission microscope detected 0.01 asbestos fibres (larger than 5 micrometres) per millilitre. Both of these readings are typical of levels after a correctly completed contract. This area had been inadequately cleaned however and large quantities of asbestos could be found on floors, equipment etc. This

indicates the need for a qualified visual inspection to ensure an effective removal project. Neither optical microscopy nor transmission electron microscopy can be used to assure complete removal of the asbestos material.

It has been noted by the author that the cost of the removal of sprayed asbestos-containing material (expressed on the basis of 1981 dollars per square metre of floor space) is declining rapidly in Ontario. This difference is most evident between the work bid (but not yet completed) in the school system in 1982 versus the work performed in the school system in 1981. Although some of this decline is due to increased competition and a lower profit margin for the contractors a larger part of the decrease is believed due to some contractors cutting corners on worker protection, area enclosure or clean-up. This may result in worker exposure to levels above the occupational standard or incomplete asbestos removal or clean-up as described in Chapter 7. When removal work is being performed it is essential that it is correctly performed. This can usually be assured by providing strict, competent inspection of the work, using correctly drafted specifications and informing the contractors prior to bidding that the specifications will be strictly enforced.

The majority of this study concerned sprayed friable asbestos-containing material. The use of friable asbestos-containing pipe or boiler insulation is likely more widespread and should also be considered in any control programme. Until the material must be removed the type of management procedures described in Chapter 1 will be an effective control measure. The one pipe and boiler insulation removal project reported in Chapter 7 indicated that removal of this insulation is much more difficult than the removal of sprayed material. When very specialized work practices are developed and experienced workers are used this removal work can also be performed without exposure of the removal workers to levels above the proposed Ontario occupational standards.

Question 6: What would these abatement projects cost Ontario building owners?

Response 6: The total area of sprayed asbestos in Ontario was estimated in Chapter 3 to be in the range of 900,000 m2 to 4,500,000 m2, with the most likely area being in the range from 1,800,000 m2 to 2,250,000 m2. The cost of removal of sprayed material discussed in Chapter 4 ranged from $13.72 to $233.78 per square metre expressed in 1981 dollars and not including the cost of moving or alternate space. The average cost of removal of sprayed material would be in the range of $50.00 to $100.00 per square metre. Therefore the total cost of removal of all sprayed material from Ontario buildings would be in the range from $45,000,000 to $450,000,000, with the most likely cost lying in the range $90,000,000 to $225,000,000 These are extremely broad ranges which are intended only to show the possible range of costs for discussion purposes. A more accurate estimate of the total area of sprayed asbestos or the total cost of the removal would require a more detailed study. It is the author's judgement that there is no need to removal all sprayed material at once, but that all sprayed friable materials should be removed prior to building demolition if the object is to prevent exposure of the demolition workers and the general population to very elevated airborne asbestos fibre concentration. The total cost of the removal may therefore be spread over a number of years but the cost expressed in 1981 dollars will likely not significantly decrease if the removal work is correctly performed. Only if removal work can be delayed until the building is emptied for removation or demolition could the total cost be reduced.

It should also be stressed that the above figures do not include the cost of removing asbestos-containing pipe or boiler insulation. Based solely on discussions with contractors and building owners it is the author's opinion that the total cost of the removal of this material will be the same order of magnitude as the removal of sprayed material.

APPENDIX A

U.S. ENVIRONMENTAL PROTECTION AGENCY

ASBESTOS EXPOSURE ASSESSMENT ALGORITHM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C 20460

OFFICE OF TOXIC SUBSTANCES

ASBESTOS EXPOSURE ASSESSMENT ALGORITHM

The attached draft exposure assessment algorithm is one alternative EPA is considering as a method for determining whether there is a significant potential for exposure to asbestos due to friable asbestos-containing materials in schools. EPA is conducting further work on this and similar schemes for assessing exposure.

DRAFT

An Exposure Assessment Algorithm

Chapter 7 "Exposure Assessment" of EPA's manual "Asbestos-Containing Materials in School Buildings: A Guidance Document" presents eight factors which should be considered by school officials when determining whether a hazardous condition exists due to the presence of friable asbestos. The guide presented here in draft suggests a method for combining these factors to obtain an "exposure number".

SEP 2 1 1

THIS EXPOSURE NUMBER IS NOT INTENDED TO STRICTLY DEFINE SPECIFIC CORRECTIVE ACTIONS FOR ASBESTOS EXPOSURE PROBLEMS. BUT SHOULD SERVE AS A GUIDE TO OFFICIAL RESPONSIBLE FOR ANALYZING THESE DECISIONS.

The exposure number may be used:

1. To determine whether corrective action can be defered or should be initiated.
2. To set priorities for decision making. The higher the scale number, the higher the priority.
3. To select a corrective action. The exposure number when compared to the Corrective Action Scale indicates methods found to be appropriate in school exposure situations.

The exposure number can not quantify a health risk. The intention of the exposure number is to serve as an indicator by which officials can determine the appropriate level of concern for an exposure area. It will aid in arranging problem areas in order of priority wherein choices can be made as to which area(s) should be addressed first.

This guide has been prepared taking into account fiber characteristics, asbestos risk factors, and experience with schools exposure situations. It does not consider factors such as duration of exposure, population characteristics, and public pressure.

There are three steps in applying the guide: (1) the eight factors are assigned a numerical value corresponding to their proper description; (2) the numerical values are combined by a mathematical formula to produce the Exposure Number; and (3) the Exposure Number is compared to the Corrective Action Scale. These three steps should be performed for each area of the building in which asbestos has been found. The three steps of the exposure guide are described below.

Step 1: Factor Score Selection

Table I presents a list of the eight factors, a brief description of the range or extent to which a particular condition applies, and a numerical "Factor Score" corresponding to that description. The official making the assessment must first select the description best fitting the situation in that area.

Only the scores indicated can be assigned to a factor. For example, "1", "3", and "4" are not acceptable scores for Factor I: Material Condition. The scores have been intentionally weighted to reflect severity of the individual factors effect on exposure potential.

The area to be evaluated should be any part of the school where the factors remain uniform. For example, an auditorium with both an inaccessibile ceiling surface in the stage area and a very accessible and damaged surface in the audience area constitutes two different areas. The scores for the two areas may exhibit a wide variation in scale number, a different assessment, and possibly different corrective actions.

Step 2: Exposure Number Calculation

The Exposure Number is derived from the Factor Scores by a formula. After entering the chosen Factor Scores on lines 1 through 8 of Table II:

a. Sum factors 1 through 6 and enter opposite SUM;
b. Multiply Factor 7 times factor 8, and enter opposite PRODUCT;
c. Multiply SUM times PRODUCT and enter opposite EXPOSURE NUMBER.

This number represents the result of your assessment for each area of the building. The Exposure Number must now be compared to the Corrective Action Scale, which is Step 3.

Step 3: Comparison of Exposure Number to Corrective Action Scale

Table III, Corrective Action Scale, presents four types of corrective action, a brief description of each, and a range of Exposure Numbers for which that Corrective Action is appropriate. Compare the Exposure Number derived in Step 2 to the ranges in Table III to determine whether action is needed. For example, an Exposure Number of 90 clearly indicates that the asbestos should be removed. An Exposure Number of 10, however, might suggest encapsulation or deferral of action. In this case it is necessary to further analyze the situation, perhaps to consider factors such as the length of time that action could be deferred or development of a management plan which would significantly reduce potential exposure.

Table 1: Factor Description and Scores

FACTOR ONE. <u>CONDITION OF MATERIAL</u>:

The condition of the asbestos materials may indicate the possibility of fibers being released to the area(i.e. contamination) and the potential for future fiber release. An assessment of the condition depends upon a combination of the

quality of the installation, adhesion of the material to the underlying substrate, deterioration, vandalism and/or damage. This factor is comprised of three levels:

A. NO DAMAGE: material is intact and shows no signs of deterioration. SCORE 0.

B. MODERATE DAMAGE: Visual inspection and physical contact indicate that the material is breaking up into layers or beginning to come loose from the substrate. There may be small areas (less than 10% of the total area) where the material is deteriorating. There may be signs of accidental or intentional damage. SCORE 2

C. SEVERE DAMAGE: The material is non-cohesive. Pieces are disloged and debris in the area is evident. Parts of the material may be hanging from the ceilings or may have fallen to the floor. Inspect for severe accidental or intentional damage SCORE 5.

FACTOR TWO: <u>WATER DAMAGE</u>

Water can dislodge, delaminate, and disturb friable asbestos materials that are otherwise in good condition. Water can carry fibers as a slurry to other areas where evaporation will leave a collection of fibers that can become reentrained (resuspended) in the air. This factor is comprised of three levels:

A. NO WATER DAMAGE: No water stains or evidence of the material being disturbed by water. No stains or buckling on the floor, ceiling or walls to indicate past water damage. SCORE 0

B. MINOR WATER DAMAGE: Small areas of the material or adjacent floor and/or walls show water stains and ceiling material may be slightly buckled. However, pieces have not fallen from the ceiling and the damage affects 10 percent or less of the material. SCORE 1

C. MODERATE TO MAJOR WATER DAMAGE: Water has dislodged some of the material and caused the material to break away, or become saturated with the potential to fall.

and/or

More than 10 percent of the material has been affected. SCORE 2.

FACTOR THREE: <u>EXPOSED SURFACE AREA</u>

The exposed surface area of friable material has an effect on potential fiber fallout levels and the possibility for contact and damage. A useful criterion for determining the amount of exposed material is whether the friable material is visible.

Asbestos material above a suspended ceiling is not considered exposed unless: (1) the ceiling panels are removed for regular maintenance, (2) the panels are damaged (i.e. due to vandalism, or maintenance) (3) the space above the ceiling comprises an air plenum.

Areas with louvers, grids, or other open ceiling systems should be considered exposed. This factor is comprised of three levels:

A. MATERIAL NOT EXPOSED: (For example, all asbestos materials are contained behind a solid suspended ceiling which is very hard to open and shows no sign of damage. The plenum is not used for air conveyance.) SCORE 0

B. TEN PERCENT OR LESS OF THE MATERIAL IS EXPOSED:(a susbended ceiling is opended occassionally or has damaged or missing panels, for example) SCORE 1

C. GREATER THAN 10 PERCENT OF THE MATERIAL IS EXPOSED: SCORE 4

FACTOR FOUR: <u>ACCESSIBILITY</u>

If the asbestos material can be reached, it is accessible and subject to accidental or intentional contact and damage. Material which is accessible (within reach) is most likely to be disturbed in the future either by accident or intentionally and, therefore, this factor is one of the most important indicators of exposure potential.

The proximity of the friable material to heating, ventilation, lighting, and plumbing systems requiring maintenance or repair indicates accessibility.

Also, the behavior of the student population should be considered in evaluating accessibility. For example, students involved in sport activities may accidently cause damage to the material on the walls and ceilings of gymnasiums. Material that is easily accessible is also subject to damage by vandalism. The presence of damage is the most obvious indicator for accessibility.

This factor is comprised of three levels:

A. NOT ACCESSIBLE: The material is located above a suspended ceiling or is concealed by ducts or piping. The building occupants cannot contact the material. Maintenance is not required for the ducts, piping or electrical systems near the asbestos materials SCORE 0.

B. RARELY ACCESSIBLE: The material is contacted only during abnormal activity such as infrequent maintenance or repair. Building occupants rarely touch the material or throw objects against it. SCORE 1.

C. ACCESSIBLE: Material is contacted frequently due to routine maintenance and/or the building occupants can contact the material during normal activity, (during this activity occupants could touch and dislodge the material or easily throw objects against it.) SCORE 4.

FACTOR FIVE. ACTIVITY AND MOVEMENT

This factor combines the effects of general causes that may result in contact or damage to friable material. These causes include air movement, building vibration from machinery or any other source, and activity levels of students or building workers. This factor is also an indication of future exposure potential. This factor is comprised of three levels:

A. NONE OR LOW ACTIVITY: In areas such as administrative offices, libraries, some classrooms, rarely used storage rooms, and fire exists. The population is quiet and non-destructive. SCORE 0

B. MODERATE ACTIVITY: Activities that could create regular vibration in cafeterias, corridors, classrooms or other areas. This vibration could result in fibers being released from the material to the immediate area. SCORE 1

C. HIGH ACTIVITY LEVEL: Occupants in cafeterias and corridors are vandalous or disruptive in their activities. Also,all gymnasiums and rooms containing machinery are subject to high vibration and air movement levels. Areas ajacent to very high sources of vibration (highways, engine shops, etc.) should be scored as "high activity level" SCORE 2

FACTOR SIX. AIR PLENUM OR DIRECT AIR STREAM

Friable asbestos-containing material within an air plenum or in an air stream if undisturbed, has a low potential of contaminating the building's environment. However, it must be considered since contamination may result from contact or damage during maintenance, repairs, renovations, or if the air stream is very turbulent. This factor is comprised of two levels:

A. NO AIR PLENUM OR DIRECT AIR STREAM PRESENT: SCORE 0.

B. AIR PLENUM OR DIRECT AIR STREAM PRESENT: SCORE 1.

An air plenum exists when the return (or, in rare cases, conditioned) air leaves a room or hall through vents in a suspended ceiling and travels at low speed and pressure through the space between the actual ceiling and the suspended ceiling. For the purpose of scoring this factor, a plenum is present if asbestos material is also found in that space. A direct air stream is present when ducts for the heating or air conditioning system blow directly on asbestos material.

FACTOR SEVEN. FRIABILITY

The term friable is applied to material that can be crumbled, pulverized, or reduced to powder in the hand. In order to score the material in question it must be touched. The asbestos-containing material can vary in degree of friability. The more friable the material, the greater the potential for asbestos fiber release and contamination. Sprayed asbestos

material is generally more friable that most trowelled materials. This factor is comprised of these levels:

A. LOW FRIABILITY: material that is difficult yet possible to damage by hand. This would include most "trowelled" materials and manufactured items such as very soft ceiling tiles. SCORE 1

B. MODERATE FRIABILITY: Fairly easy to dislodge and crush or pulverize by hand. Material may be removed in small or large pieces. SCORE 2

C. HIGH FRIABILITY: The material is fluffy, spongy, or flaking and may have pieces hanging down. SCORE 3

FACTOR EIGHT: ASBESTOS CONTENT

The percentage for all types of asbestos present in a given sample should be added for the total asbestos content. While all asbestos materials present an exposure potential, those with a high percentage of asbestos can release more fibers. This factor is comprised of three levels:

A. TRACE AMOUNTS TO ONE PERCENT: SCORE 0.

B. ONE PERCENT TO FIFTY PERCENT: SCORE 2.

C. FIFTY PERCENT PLUS: SCORE 3.

These levels of asbestos content must be derived from results of bulk sample analysis. Building records or assumptions are not reliable or acceptable

Table II. Exposure Number Calculation

Factor		Factor Score
1. Material Condition		
2. Water Damage	+	
3. Exposed Surface Area	+	
4. Accessibility	+	
5. Activity and Movement	+	
6. Air Plenum	+	________
SUM [1 + 2 + 3 + 4 + 5 + 6]	=	
7. Percent Content		
8. Friability	x	________
PRODUCT [7 x 8]	=	
Exposure Number = PRODUCT x SUM	=	________

Table III. Corrective Action Scale

EXPOSURE NUMBER RANGE		CORRECTIVE ACTION
0 - 12		DEFERRED ACTION
Advantage:	There is no direct cost associated	
Disadvantages:	(1) The potential for exposure may increase.	
	(2) A management system is required. Precautions are necessary to prevent damage during maintenance or renovation.	
	(3) It is necessary to have continous inspection and reevaluation.	
When Appropriate:	When there is negligible exposure potential.	
When Inappropriate:	(1) When there is definite or questionable exposure potential.	
	(2) Continuing inspection is doubtful	
10-50		ENCAPSULATION
Advantage:	(1) It controls fiber release	
	(2) It is a rapid and economical method	
Disadvantages:	(1) The asbestos source remains.	
	(2) If the material is damaged or deteriorating the additional weight of the sealant may cause layers of the material to break away from the underlying surface.	
	(3) A management system is required. Precautions are necessary to prevent damage during maintence or renovation.	
	(4) Continuing inspection and maintenance for damage or deterioration to	

encapsulated surface. (i.e. future potential for fiber release is possible).

(5) Encapsulated material is very difficult to remove if it becomes necessary.

When Appropriate:

(1) When removal is not feasible

(2) The material still retains bonding integrity.

(3) Damage to the material is not probable.

(4) Accessibility to material is limited

(5) The surface in question is complex (i.e. pipes, lines and ducts).

(6) When economic or time constraints are present.

When Inappropriate:

(1) When removal is feasible

(2) Material does not adhere well to the substrate. The weight of the sealant may cause futher damage.

(3) When the material is deteriorating or damaged.

(4) Damage to the material is probable

(5) Water damage or the potential for water damage is evident.

(6) High accessibility present

(7) When continuing inspection and maintenance of encapsulated material is doubtful.

10-50 <u>ENCLOSURE</u>

Advantage:

(1) It controls fiber release

(2) May be the most rapid, economical and uncomplicated method.

Disadvantage:

(1) The asbestos source remains

(2) Fiber fall out continues behind the enclosure

(3) Maybe costly if enclosure disturbs functions of other systems (e.g. enclosure may require lighting changes).

(4) Management system required. Precautions necessary for entry into enclosure for maintenance or renovation.

(5) Continuing inspection and maintenance of damage to enclosure system required.

When Appropriate:

(1) Removal is not feasible.

(2) Disturbance or entry into enclosed area is not likely.

(3) Economic constraints are present

When Inappropriate:

(1) Removal is feasible

(2) Damaged or deteriorating material causes high level of fiber fallout.

(3) Water damage to enclosure is likely

(4) Entry into enclosure probable for repairs and maintenance.

REMOVAL

40 and over

Advantage:

(1) It eliminates the asbestos source

(2) Ends the exposure and precludes the development of future problems.

Disadvantages:

(1) Usually the most costly, complicated and time consuming method.

(2) Replacement with substitute material may be necessary.

(3) Higher potential for worker exposure during removal

When Appropriate:

(1) High exposure exists.

(2) Material is deteriorating, high accessible and has severe water damage.

(3) Open material surfaces.

When Inappropriate:

(1) When removal is not feasible because of cost, location of material and kind of surface to which material has been applied (e.g. removal of material from complex surfaces such as pipes, lines and ducts).

Summary:

(1) If exposure number is 0-12 usually can defer action.

(2) If exposure number is approximately 40 or over removal is probably the best corrective action.

(3) If the exposure number is 10-50 and has high water damage or accessibility factor, removal is probable the best corrective procedure.

(4) If the exposure number is 10-50 and the water damage and accessibility factors are low, then the constraints (i.e. economic, time and complicated surfaces) need to be examined. The three corrective actions possible are incapsulation, enclosure and removal.

APPENDIX B

BOARD OF EDUCATION FOR THE CITY OF TORONTO

MODIFIED FERRIS INDEX

The method used by the City of Toronto School Board for a comparative evaluation of the risk potential between buildings involved detailing the seven factors shown in the table below. The method was only applied to buildings with friable-asbestos containing material. Each of the "Ferris Weight" factors was multiplied by the appropriate level of concern to give a total. Fifty points for each 10% increment of asbestos content were added to this. Finally either 250 points for chrysotile or 500 points for amosite were added to this to give a grand total.

SAMPLE ASSESSMENT REPORT
(Modified Ferris)

School:

Description:

Category	Ferris Weight	Level of Concern (Multiplier) 0	1	2	3	Total
Friability	100					
Condition	100					
Accessibility	50					
Air Plenum/ Direct Exposure	50					
Activity & Movement	25					
% Asbestos		Weighted 50 per increment of 10% asbestos content.				
Type of Asbestos		Weighted Amosite - 500 Chrysotile - 250				

GRAND TOTAL

A separate table was completed for each type of material in each building. To provide a single number for each building these individual results could be averaged. All buildings were then ranked in descending order.

The order of ranking was not strictly followed as other factors were considered before a decision was made. These factors include

: need to perform other work in the building which may disturb asbestos

: emergency conditions created by flood or fire

: imminent determination to close a school because of falling enrolment

: desireability of performing work as soon as possible. This results in work that can be dealt with when buildings are occupied or on short holiday breaks being performed before work which must wait for the summer holiday closing

APPENDIX C

U.S. NAVY RISK EVALUATION INDEX

Chapter 5

RISK EVALUATION

If bulk material analysis establishes that friable asbestos insulation material is present in samples obtained from a facility, potential exposure of occupants as well as other users of the structure should be assumed, requiring a thorough assessment of the magnitude of exposure. An asbestos hazard index for a given situation combines observations and judgments about several factors and elements, as collected on the Asbestos FIM Evaluation Form (see pages 5-15 through 5-17), describing the facility and its occupancy level. Factors may act singly or in combination to cause environmental contamination and exposure of structural occupants.

The asbestos hazard index number value of a particular asbestos situation can be used to decide between: (1) deferring action with interim control measures and planned periodic reviews of the situation in case of deterioration or other change; or (2) initiating action with interim and long term control measures, including a NAVOSH asbestos deficiency abatement project. The asbestos hazard index number value is also used to rank a number of situations in priority order from high to low in terms of potential health hazards. The greater the asbestos hazard index number value, the more severe is the hazard created by the friable asbestos in that building, and the more desirable it becomes to initiate a NAVOSH asbestos deficiency abatement project.

NOTE

The asbestos hazard index number produced by this technique is designed for rating asbestos hazards in a relative fashion only and should not be interpreted beyond these uses.

LOGIC OF THE HAZARD INDEX

The logic of this hazard index assessment is simple and can be readily explained. The potential health hazard associated with the presence of friable asbestos depends on the level of exposure, the number of persons exposed to asbestos fibers, and the duration of exposure. The logic of this hazard index system is portrayed graphically in Figure 5-1.

NOTE

> "Potential hazard" for purposes of this document is defined as the potential health consequences of a hazardous situation, including disease, death, medical costs, disability awards, human suffering, and other indirect costs and burdens.

Level of Exposure

The following five elements are needed to estimate the potential level of exposure to asbestos fibers that may be in the air in the FIM rooms of the building being analyzed:

1. FIM percent asbestos fiber, including all kinds, contents or concentrations as determined by bulk material laboratory analysis (Appendix A).

2. FIM inherent friability (the degree to which the fibrous material is not bonded together or sealed and therefore may potentially release fibers).

3. FIM accessibility to occupants and frequency of maintenance or repair disturbance.

4. FIM current condition of damage or deterioration causing potential friable material surface fiber release.

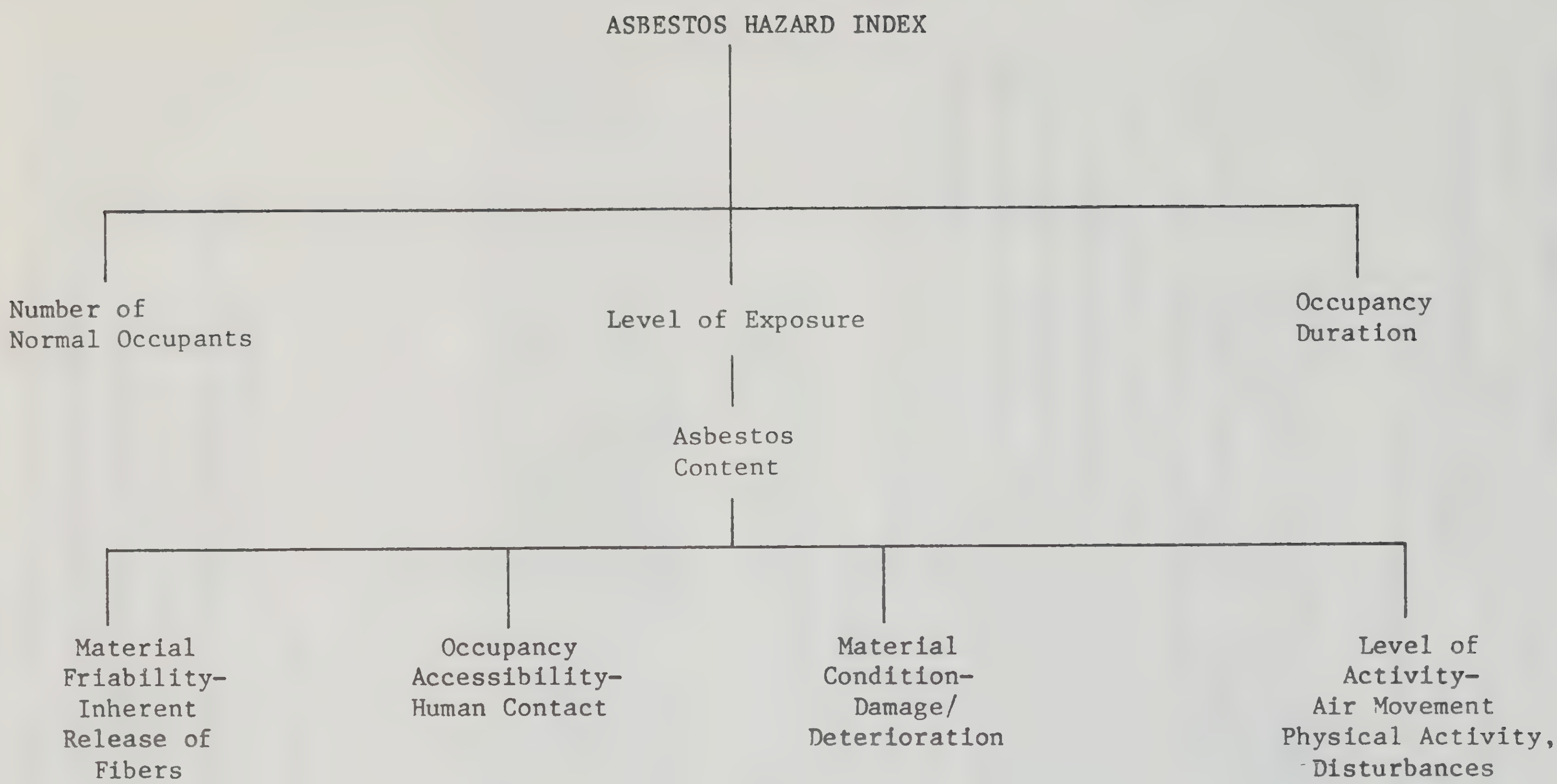

Figure 5-1. How factors combine to produce a hazard index.

5. Level of activity in the spaces which may potentially disturb the FIM and cause fibers to be released into the air, causing potential exposure risk to occupants. Activities may also cause reentrainment of accumulated, settled fibers.

Number of Assigned Occupants

Even when exposed to relatively high concentrations of respirable asbestos fibers, the probability that any single individual will suffer any adverse health effects is extremely small. As the number of people exposed to a particular concentration of airborne asbestos fibers increases, however, the chance of some adverse effects also increases. Therefore, the asbestos hazard index number value will, of course, be greater for a situation where large numbers of people are exposed to friable asbestos material than for a situation where lesser numbers of people are exposed to the same fiber level.

Occupancy Duration

Because asbestos fibers are cumulative and not biodegradable in the human body, the length of time an individual is exposed to a given level of asbestos fibers contributes to the likelihood of adverse health effects. Therefore, the asbestos hazard index number value will be greater when the number of hours that individuals are exposed in a year is greater.

ASBESTOS FIM EVALUATION FORM

The Asbestos FIM Evaluation Form at the end of this chapter presents a checklist for collecting information that should be used in evaluating asbestos hazard index number values associated with possible asbestos exposure, selecting an appropriate corrective action and in preparing a NAVOSH Asbestos Deficiency Abatement Project. Details of the form are presented in this chapter.

Level of Exposure Factors

Material Friability (Item 1*).

NOTE

Friable asbestos materials are defined as any materials that contain more than 1% asbestos, by weight, and can be crumbled, pulverized, or reduced to powder when dry, by hand pressure.

Asbestos materials vary in degree of friability: the more friable the material, the greater the potential for asbestos fiber release and contamination. To evaluate the FIM material in question, material must be touched.

NOTE

Use proper respirator and hand protection (Appendix B) during the crumbling of the material.

Occupant Accessibility (Item 2). If the material is vulnerable to human activity, or is subject to accidental or intentional contact, it should be considered an accessible exposure. Structure use is to be considered in evaluating this element. For example:

1. FIM on a 14-foot high ceiling in office space is normally inaccessible; however, the same ceiling height in a warehouse can be subject to contact.

2. In a gymnasium, walls are subject to greater contact than the ceiling, either by sports equipment or spectators.

3. FIM on the low ceilings of corridors and stairwells are subject to extensive damage from accidental or intentional contact and damage.

*Item numbers refer to numbers on the Asbestos FIM Evaluation Form.

Material Condition (Item 3). Damage to material integrity indicates the extent of existing contamination and the degree of potential contamination. This element is a combination of the quality of installation, adhesion of the friable material to the underlying surface, cohesion of the insulating material itself, and material aging. Evidence of debris is often a good clue to the condition of material, which may vary from minor deterioration to widespread and severe material disintegration.

Although water damage information is not required on the Asbestos FIM Evaluation Form, information should be noted and maintained for future use when selecting long-term control measures. Because of leaks or capillary action into or between the FIM and the substrate, water can dislodge, delaminate, and disturb asbestos materials that are otherwise in excellent condition. Water damage may be caused by roof leaks, condensation accumulating on the structural surface or within the FIM, or water pipe problems adjacent to the FIM or on the floor above or inside walls.

Level of Activity (Item 4). If a friable material is disturbed by vibrations or physical contact, it is much more likely to release fibers into the air. Level of activity can be caused by noise vibrations, machinery vibration, turbulent air flows, or the physical activities of the occupants of the building. External noises such as aircraft, heavy traffic, and manufacturing may cause vibrations within the FIM building, greatly increasing the potential for fiber release.

FIM Fiber Content (Item 5). The percentage for all types of asbestos present should be added to obtain the total asbestos content of the material. The percentage data can be obtained from the CEL bulk material analysis or petrographic microscopy analysis (Appendix A). When a high percentage of asbestos is present, the potential for fiber release increases.

Number of Assigned Occupants (Item 7). The number of assigned occupants is determined by the number of persons whose activities are conducted on a routine basis in the rooms containing the asbestos FIM.

Only the assigned workshift level in rooms where FIM is located should be counted. If the structure is frequently used by the public, this element should be noted in Item 13, Structure Utilization by the Public.

NOTE

> If FIM is present on the plenum surfaces and inside of return air systems, the total number of building occupants should be counted.

Occupancy Duration (Item 8). Occupancy duration is determined by the length of time a particular individual is exposed to asbestos FIM in each 40-hour week.

Management Special Considerations/Remarks

Management special considerations are elements not addressed in the structural, occupancy factors, or activity level sections of the Asbestos FIM Evaluation Form. Management special considerations/ remarks include such factors as utility maintenance frequency, life cycle projection for the structure and building utilization by other than Navy personnel.

Utility Maintenance Frequency (Item 10). Utility maintenance in the structure, particularly in rooms with asbestos FIM, can be a major problem. The Public Works Departments should establish work procedures for protecting personnel against potential fiber release. If maintenance occurs frequently close to FIM, this factor will strongly influence selection of corrective-action type. For example, buildings with communication or computer equipment have a high requirement for changes in configuration; thus FIM disturbance frequency is potentially high.

Life Cycle Projection for Structure (Item 11). The life cycle projection for the building should include the following considerations:

a. Future intended use

b. Possibility of major renovation projects

c. Possibility of closure or designating building as a limited access area for authorized personnel only

If the building will be used for a substantial number of years, long-term corrective action should be considered, if appropriate. The future intended use of the structure must be considered when selecting corrective action. If the building is of general construction in nature, it may be used throughout its life cycle by several major claimants, therefore it may potentially require several renovations. It should be noted that for each instance of building renovation, the presence of FIM must be taken into consideration. However, if the structure is unique, possibility of change in use is unlikely, and the life cycle is fairly well fixed.

If the structure is expendable to the command, the possibility of closure should be considered. However, if the building is required for storage, or the room is part of a penthouse or utility distribution system, a limited access area may be designated for authorized personnel only. If either one of these types of actions (closure or limited access) is taken, a management system must be used. The system should include:

a. Proper sign-posting of the area

b. Protective equipment for personnel entering FIM areas

c. A flagging system for the building maintenance record warning of the presence of asbestos

<u>Renovation Schedule (Item 12)</u>. The renovation schedule or possibility of renovation should also be considered in the management process. During the majority of renovations, the asbestos FIM will potentially be directly or indirectly involved. If renovation occurs frequently, this element should be taken into consideration when selecting

corrective action. For example, if the building has inadequate lighting or heating, and the FIM is left in place, the FIM will be disturbed during the changing of fixtures.

Structure Utilization by the Public (Item 13). Information regarding the frequency and number of visitors to the FIM building should be noted. Information may be required to aid in prioritization of a NAVOSH asbestos deficiency abatement project. If the structure is frequently used by the public and vandalism is a problem, long-term corrective action that will prevent asbestos FIM access should be selected. Vandalism can create significant exposure to persons in the vicinity of the occurrence.

Other Unique Characteristics (Item 14). This section of the evaluation provides space for any unique building characteristics which would affect the decision to submit a NAVOSH Asbestos Deficiency Abatement Project.

Steps in Calculating a Hazard Index for a Building

Information noted on the Asbestos FIM Evaluation Form is used to determine asbestos hazard index number values. Five steps are taken when calculating an asbestos hazard index number value. Note, however, that if a building contains more than one potential asbestos-releasing situation or room with a significantly different problem as far as condition, occupancy, or kind of abatement action to be considered, potential hazards should be considered as separate entities. The method used to establish the Asbestos Hazard Index combines the Level of Exposure Elements and Level of Exposure Factors. Level of Exposure Factors relied on experience with the EPA's asbestos program and upon scientific, medical, and engineering advice. As can be seen in Table 5-1, ratings range from 0.0002 to 470,000. This very wide spread is believed by experts to represent the actual spread from the least dangerous to the most potentially hazardous asbestos situations and indicates how much difference in probability of health effects may exist for different building situations.

Table 5-1. Determining Level of Exposure Factors[a]

Level-of-Exposure Elements				Level-of-Exposure Factors Based on Following Asbestos Contents (Item 5)		
Item 1 Material Friability	Item 2 Occupant Accessibility	Item 3 Material Condition	Item 4 Level of Activity	Low (1%-9%)	Medium (10%-39%)	High (40%-100%)
Low	Low	Good	Low	0.0002	0.0011	0.0031
Low	Low	Poor	Low	0.0056	0.0031	0.0087
Low	Low	Good	Moderate	0.0011	0.0065	0.018
Low	Low	Poor	Moderate	0.0031	0.018	0.050
Low	Low	Good	High	0.0065	0.037	0.102
Low	Low	Poor	High	0.018	0.10	0.28
Low	Moderate	Good	Low	0.065	0.37	1.0
Low	Moderate	Poor	Low	0.18	1.0	2.8
Low	Moderate	Good	Moderate	0.37	2.1	5.8
Low	Moderate	Poor	Moderate	1.0	5.8	16.0
Low	Moderate	Good	High	2.1	12.0	33.0
Low	Moderate	Poor	High	5.8	33.0	92.0
Low	High	Good	Low	0.18	1.0	2.8
Low	High	Poor	Low	0.497	2.8	7.9
Low	High	Good	Moderate	1.0	5.8	16.2
Low	High	Poor	Moderate	2.8	16.3	45.0
Low	High	Good	High	5.8	33.0	92.0
Low	High	Poor	High	16.0	92.0	260.0
Moderate	Low	Good	Low	0.065	0.37	1.0
Moderate	Low	Poor	Low	0.18	1.0	2.8
Moderate	Low	Good	Moderate	0.37	2.1	5.8
Moderate	Low	Poor	Moderate	1.0	5.8	16.0
Moderate	Low	Good	High	2.1	12.0	33.0
Moderate	Low	Poor	High	5.8	33.0	92.0
Moderate	Moderate	Good	Low	21.0	120.0	330.0
Moderate	Moderate	Poor	Low	58.0	330.0	920.0
Moderate	Moderate	Good	Moderate	120.0	690.0	1,900.0

continued

Table 5-1. Continued

Level-of-Exposure Elements				Level-of-Exposure Factors Based on Following Asbestos Contents (Item 5)		
Item 1 Material Friability	Item 2 Occupant Accessibility	Item 3 Material Condition	Item 4 Level of Activity	Low (1%-9%)	Medium (10%-39%)	High (40%-100%)
Moderate	Moderate	Poor	Moderate	330.0	1,900.0	5,300.0
Moderate	Moderate	Good	High	690.0	3,900.0	11,000.0
Moderate	Moderate	Poor	High	1,900.0	11,000.0	30,000.0
Moderate	High	Good	Low	58.0	330.0	920.0
Moderate	High	Poor	Low	160.0	920.0	2,600.0
Moderate	High	Good	Moderate	330.0	1,900.0	5,300.0
Moderate	High	Poor	Moderate	920.0	5,300.0	15,000.0
Moderate	High	Good	High	1,900.0	11,000.0	30,000.0
Moderate	High	Poor	High	5,300.0	30,000.0	83,000.0
High	Low	Good	Low	0.37	2.1	5.8
High	Low	Poor	Low	1.0	5.8	16.2
High	Low	Good	Moderate	2.1	12.0	33.0
High	Low	Poor	Moderate	5.8	33.0	92.0
High	Low	Good	High	12.0	69.0	190.0
High	Low	Poor	High	33.0	190.0	530.0
High	Moderate	Good	Low	120.0	690.0	1,900.0
High	Moderate	Poor	Low	330.0	1,900.0	5,300.0
High	Moderate	Good	Moderate	690.0	3,900.0	11,000.0
High	Moderate	Poor	Moderate	1,900.0	11,000.0	30,000.0
High	Moderate	Good	High	3,900.0	22,000.0	62,000.0
High	Moderate	Poor	High	11,000.0	62,000.0	170,000.0
High	High	Good	Low	330.0	1,900.0	5,300.0
High	High	Poor	Low	920.0	5,300.0	15,000.0
High	High	Good	Moderate	1,900.0	11,000.0	30,000.0
High	High	Poor	Moderate	5,300.0	30,000.0	83,000.0
High	High	Good	High	11,000.0	62,000.0	170,000.0
High	High	Poor	High	30,000.0	170,000.0	470,000.0

[a] Step 2 in calculating a hazard index for a building.

NOTE

> A set of statistical weights was not used because of the qualitative nature of input judgments and of the medical and engineering advice. Also, it is believed that many of the relationships between input estimates and potential exposure level are nonlinear and subject to differing degrees of variability of judgment over the many situations that may be observed.

Step One. Complete Asbestos FIM Evaluation Form. Information should be recorded as completely as possible during the FIM evaluation. All applicable information should be recorded while still inside the building being surveyed.

Step Two. Determine Level of Exposure Factor. The qualitative elements (Items 1 through 4) in combination with the asbestos content (Item 5) are used to produce an estimated potential asbestos level of exposure. Table 5-1 presents tabulated values for the four elements and asbestos content used for determining the level of exposure factor. The exposure factor should be entered in Item 6.

Step Three. Determine Occupancy Number. Determine the number of persons who normally occupy FIM containing areas.

Step Four. Determine Occupancy Duration. Determine the average time duration of the Occupancy Number (Step Three) for a 40-hour week.

Step Five. Calculate Asbestos Hazard Index. Multiply the three values – level of exposure, number of normal occupants, and occupancy duration – together, then divide by 40 (hours per week) to produce an asbestos hazard index number value (Item 9) for a given FIM building circumstance.

Item 6		Item 7		Item 8			Hazard Index Number (Item 9)
☐	x	☐	x	☐	/40 (hr/wk)	=	☐

DECISIONS ON INITIATION OF ABATEMENT ACTION

The asbestos hazard index number value for a particular building situation should first be used to decide whether to initiate interim control measures or interim and long-term control measures. Table 5-2 presents recommended action categories in accordance with the hazard index number value.

If the asbestos hazard index number value is between 100 to 1,000, the Management Considerations/Remarks Section of the Asbestos FIM Evaluation Form should be reviewed to determine appropriate corrective action.

Table 5-2. Hazard Action Guide

Hazard Index Value	Recommended Action Categories
Less Than 100	A long-term corrective measure can usually be deferred; however, the building should be surveyed each year for evidence of change in conditions (deterioration) or occupancy level. Interim control measures should be initiated (see Chapter 6).
100 and 1,000	Review management special considerations/remarks (Items 8-12 on the Asbestos FIM Evaluation Form), as necessary to further analyze the situation for action justification; defer unless these considerations justify long-term control measures.
Over 1,000	NAVOSH Asbestos Deficiency Abatement Project for long-term control measures should be initiated (see Chapter 6 for selecting appropriate corrective measure)

Hazard Action Guide

It is believed that the Hazard Action Guide is a good indicator of current Navy judgments and policy decisions. It indicates the kind of asbestos hazard index number values of candidate building situations that will be given consideration for NAVOSH asbestos deficiency abatement project funding.

Air Monitoring Considerations

The level of human exposure to asbestos fibers in a situation can be estimated by a Navy industrial hygienist using air sampling techniques (Chapter 4 and Appendix A) that provide an actual count of the number of fibers per cubic centimeter (f/cc) greater than 5 μm in length. However, air sampling itself is subject to measurement inaccuracies inherent with the methodology employed. Also, it provides only an estimate of the actual number of fibers in the air at one moment, in a situation that may vary widely over the day and vary widely in the future months and years. Levels may vary depending on the level of the activities in the building, as well as changes in the building condition (see Chapter 4 for details).

Air monitoring should be conducted in FIM containing rooms with an asbestos hazard index number value above 100 to determine if any violation of health standards is evident. This data should be used as a supplement to the NAVOSH asbestos deficiency abatement project request.

If air samples at any time indicate a condition where the fiber level exceeds 0.1 f/cc (greater than 5 μm in length), action to investigate the source and interim control measures should be initiated immediately.

NAVOSH ASBESTOS DEFICIENCY ABATEMENT PROJECT

After the identification of the friable asbestos insulating material, installation commanders will have to conduct an in-depth evaluation of data from the Asbestos FIM Evaluation Form (Figure 5-2) and air monitoring surveys to determine the recommended action category. When appropriate, a corrective project should be developed and submitted in accordance with OPNAVINST 5100.23 of May 1979 and current Naval Facilities Engineering Command instructions on the NAVOSH deficiency abatement program. The latest of these instructions can be obtained from the Naval Energy and Environmental Support Office, Naval Construction Battalion Center, Port Hueneme, Calif. 93043.

ASBESTOS FIM

EVALUATION FORM

UIC ______ NUMBER OF FACILITY ______

EVALUATOR ______ DATE ______

Check appropriate item or write in an answer where required for applicable categories.

LEVEL OF EXPOSURE ELEMENTS

1. Material Friability

______	Low Friability:	material difficult to crumble by hand
______	Moderate Friability:	material fairly easy to dislodge and crush
______	High Friability:	material easily reduced to powder or broken by hand

2. Occupant Accessibility

______	Low Accessibility:	Materials are not exposed; totally isolated by permanent barrier or accessible only during infrequent, occasional maintenance activity; no air flow from the FIM location to occupants of the building.
______	Moderate Accessibility:	Only a small percentage of material exposed; material above a suspended ceiling; material contacted only during maintenance or repair; material exposed, but not accessible to activity of normal occupants.
______	High Accessibility:	A large percentage of material exposed; material accessible to occupants or airborne transport during normal activities.

Figure 5-2. Asbestos FIM Evaluation Form.

3. Material Condition

_______ Good condition: deterioration and/or damage not visible; or minor damage evident only in isolated areas.

_______ Poor Condition: Deterioration apparent; damage visible in more than one area; dislodged pieces evident.

4. Level of Activity

_______	Low Activity:	Neither routine or unusual disturbances by vibrations or physical contact are expected.
_______	Moderate Activity:	Moderate disturbances occur in rooms with vibrating machinery, high noise levels, or strenuous activity by occupants; turbulent air streams from ducts and vents carrying air across the material.
_______	High Activity:	Heavy disturbances caused by the noise and vibrations associated with heavy manufacturing operations; regular movement of forklift trucks; material in plenum and return air systems; vibrations from external noise.

5. FIM Fiber Content

_______ % Total asbestos

6. Level of exposure factor (from Table 5-1) _______________

NUMBER OF ASSIGNED OCCUPANTS

7. Assigned Occupancy level in FIM containing workspace.

_______ Number of persons

OCCUPANCY DURATION

8. Time duration of average exposure per person

_______ Hours per 40 hour week

Figure 5-2. Continued.

9. Calculate Asbestos Hazard Index: Multiply the three values -- level of exposure (determined from Table 1 using Items 1-5), number of normal occupants (Item 7), and occupancy duration (Item 8) -- divided by 40 (hr/wk) to produce an asbestos Hazard Index Number.

Item 6		Item 7		Item 8			Hazard Index Number
☐	x	☐	x	☐	/40 (hr/wk)	=	☐

MANAGEMENT SPECIAL CONSIDERATIONS/REMARKS

10. Utility maintenance frequency.

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11. Life cycle projection for structure.

---

12. Renovation schedule.

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13. Structure utilization by the public.

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14. Other unique characteristics.

Figure 5-2. Continued.

APPENDIX D

U.S. NAVY FACILITY HYGIENE PRACTICES

ASBESTOS THERMAL INSULATION

Technical Note

CEL

TN no. N-1591

title: FACILITY HYGIENE PRACTICES ASSOCIATED WITH ASBESTOS THERMAL INSULATION

author: E. E. Lory

date: October 1980

sponsor: Naval Facilities Engineering Command

program nos: YF65.572.091.01.008

CIVIL ENGINEERING LABORATORY

NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

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FOREWORD

Occupational Safety and Health Administration (OSHA) Standards imposed on the Navy by Executive Order 11612 and 11807, followed by OPNAVINST 5100.8C and 6240.30, require implementation of health and safety methods for Naval personnel. OSHA Standard 1910.1001 and OPNAVINST 6260.1A are concerned with the control of asbestos emissions for the protection of personnel and the environment.

OSHA regulations must be adhered to by all Federal agencies. Work performed by Public Works Departments or by private contractors aboard Naval installations must comply with these regulations.

INTRODUCTION

The Civil Engineering Laboratory (CEL) has been tasked by the Naval Facilities Engineering Command (NAVFAC) to develop guidance on appropriate practices for cleaning workplaces that have significant amounts of asbestos-containing thermal insulation. Many types of asbestos insulation products have been used in Navy construction in a variety of steam and hot water systems. The diversity and various states of maintenance have led to concern in determining appropriate practices for facility hygiene. Also, when the new Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) regulations came into force, the protection of workers from industrial disease became a statutory obligation wherever asbestos materials are used in such a way as to give rise to the emission of dust dangerous to the health of employees. These regulations have placed new burdens on facility and safety managers to insure proper practices for removing accumulated hazardous asbestos dust and achieving satisfactory working conditions.

This technical note is one of a series of documents prepared by CEL on asbestos construction products at Naval Shore Facilities. The primary guidance document is the Management Procedure for Assessment of Friable Asbestos Insulating Products (Ref 1). The information assembled in this investigation was developed through a search of pertinent literature and through contacts with EPA. This type of information is essential to facility and safety managers to insure regulation compliance and cost-effective operations. Also, it provides a basis for decisions regarding the direction of further development in this area. Supplementary technical notes to this guidance document will be prepared on subjects related to asbestos-containing products, such as encapsulation methods, thermal pipe insulation maintenance procedures, applied insulation demolition techniques, and handling and disposal of asbestos-containing waste.

BACKGROUND

Asbestos is a general term used to describe several fibrous hydrated silicate minerals known for their high tensile strength, high flexibility, durability, and heat and chemical resistance. Only six of these asbestiform silicates -- chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite -- are of major commercial importance. In the past decade, there has been an increasing awareness of the significance of environmental contamination as a cause of disease. The physical characteristics of asbestos fibers and the widespread and varied uses of asbestos-containing products have caused concern for human exposure within buildings that contain such material. The hazard potential from such exposure for the population involved may be relatively high. Because of widespread use and ease of fiber dissemination, asbestos-containing thermal insulation can be considered one of the most significant sources of asbestos fibers in the indoor environment.

The potential for fibers to enter the workspace environment depends upon type of construction material, structural form, and building use. Fiber dissemination is a function of the frequency and amount of energy delivered to the asbestos-containing material, normally through the generation of air currents and mechanical agitation.

Relevant characteristics of asbestos fibers include durability and high aerodynamic capability, both of which directly influence the probability for long-term contact. Once in the workspace, the fibers exhibit low settling velocities, remaining in the inhalation contact zone for long periods of time. As calculated from settling curves generated specifically for asbestos fibers, a 1.0 μm fiber with a 5:1 aspect ratio, falling from 3 meters with variable axis attitude, will exhibit a settling velocity of 10^{-3} cm/sec and remain airborne for over 80 hours. Furthermore, settled fibers have aerodynamic capability and may experience reentrainment cycles if disturbed. Such fibers contained within workspaces can repeatedly present an exposure situation and an opportunity for inhalation or ingestion.

ENVIRONMENTAL MONITORING

Airborne asbestos dust is usually monitored for one of three reasons. First, large numbers of samples are taken to check compliance with legislation with regard to persons involved directly in asbestos control measures. Second, determinations are made regarding the efficacy of engineering dust suppression measures. Last, the asbestos is monitored for epidemiologic purposes. Therefore, air monitoring is used to estimate concentration levels of airborne fiber before, during, and after facility hygiene operations. The federal government requires monitoring of employee exposure to determine whether each employee's exposure to asbestos fibers is below the current limits.

Sampling and analysis for airborne asbestos may establish the existence of asbestos contamination (see Reference 1 for details). An adequate study of airborne contamination requires sampling during various indoor activities and sampling of outside or community ambient levels, with inclusion of control samples. Sampling within a structure under only quiet conditions may be particularly misleading because asbestos fibers usually become airborne as a result of disturbance through human activity. Direct monitoring of persons engaged in these activities will best define potential exposures.

MAINTENANCE OF THERMAL INSULATION

In facilities with asbestos-containing thermal insulation, all machinery, equipment, and internal surfaces of the building should be kept, so far as is practicable, in a clean state and free from asbestos waste and dust. Scheduled preventive maintenance and inspection of thermal insulating systems should be conducted at least once a year, but preferably at 6-month intervals. Reliability of the piping system and trouble-free service life can be increased by such scheduling. Preventive maintenance also insures maximum thermal conservation.

Another aspect of the preventive maintenance inspection is locating pipe insulation damage, which is a potential source of asbestos fiber release and subsequent exposure of workers. Fiber release is dependent on the extent of damage, the incidence of repeated disturbance, and available air currents or turbulence to carry the hazardous fibers into the respirable (breathing) zone. It should be noted that when thermal pipe insulation, including asbestos-containing insulation, is properly maintained and lagged, there is no danger of fiber release.

All damaged thermal insulation should be repaired before the facility's hygiene operation begins (see Reference 1 for details). Proper maintenance will protect the insulation from further damage and will also prevent fiber disturbance during the cleaning operation.

SAFETY PROCEDURES FOR PERSONNEL PROTECTION

Safety and health requirements for conforming with OSHA, EPA, and Navy regulations must be complied with according to exposure levels when work is to be accomplished by Navy personnel, civilian personnel, or outside contractors. To insure personnel are not being exposed to asbestos fiber levels, protective equipment must be worn.

Any respirator used must be approved for protection against exposure to asbestos by the Mine Safety and Health Administration (MSHA, formerly MESA) or the National Institute for Occupational Safety and Health (NIOSH). For facility hygiene operations (i.e., nonrip-out asbestos operations), the type of respirator is determined by the asbestos fiber concentration in the breathing zone during worst case conditions. Generally, reusable or disposable single-use air purifying respirators will provide the required protection.

Disposable headcovers and shoe covers, coveralls (or a disposable sock suit constructed of TWEK or other similar material documented to be of equivalent resistance to penetration of asbestos), gloves, and goggles are generally recommended.

For additional guidance, the cognizant safety specialist or industrial hygienist should be consulted.

RECOMMENDED HYGIENE PROCEDURES

Procedures for facility hygiene operations have been described by the Asbestos Research Council (Ref 2). Their recommendations include the following.

Floors

Contamination of working areas from accumulation of waste material on floors must be avoided by regularly cleaning with a dustless method. The first choice of a dustless method for cleaning would be by vacuum, either from a fixed source or a mobile unit. Alternative methods would include thorough damp mopping of the floor or the use of chemical-impregnated mops.

Walls

Annual cleaning of the walls should be sufficient. Walls may be cleaned either by vacuuming or by washing down using amended water.

Machinery and Equipment

The method to be used for cleaning equipment depends on the degree of contamination, the type of material, and whether the material is contaminated with oil or water. It is preferable to use vacuum cleaners, either of the fixed or mobile type, with suitable extension leads. Inaccessible parts of the equipment may be cleaned out with chemical-impregnated brushes or cloths and then vacuum equipment used to collect the material so removed.

Overhead

The most difficult cleaning operation that has to be undertaken on a regular basis in any facility with significant asbestos materials is overhead cleaning in high buildings. The frequency of cleaning overhead structures will vary significantly from one facility to another. As a general guide, overhead structures should be cleaned once a year or when asbestos dust has accumulated.

Ideally, either permanent or mobile lightweight staging would be used by the cleaners to reach the areas that are inaccessible from ground level. Where there are no obstructions at ground level, telescoping equipment would be suitable.

If an area could possibly contain dust, it should be removed by vacuuming, using extension hoses where necessary. Some places may, however, be inaccessible or the accumulation of dust be tenacious; in these cases, it will be necessary to resort to hand brushing with chemical-impregnated equipment.

Where dustless methods of cleaning are not practicable, protective clothing and approved respirators must be worn by all personnel present in the building. It is recommended that such protective clothing and respirators be worn by all personnel engaged in overhead cleaning regardless of the method used.

Equipment located beneath an overhead cleaning area should be covered with plastic sheets, so far as is practicable, in order to simplify the subsequent general cleaning of the area.

Since overhead cleaning may only be possible when work is stopped, cleaning may have to be scheduled for weekends. Night cleaning is not recommended because the area being cleaned is above the level of the light fixtures and, therefore, the lighting is usually inadequate. Cleaning may be undertaken by contract cleaners. However, the nature of the hazard must be made clear to the contractor, and the contractor must comply with all regulations.

RECOMMENDED CLEANING METHODS

All necessary cleaning must be by vacuum or by wet or chemical cleaning, since dry sweeping and similar procedures create more, rather than fewer, dust problems. Under NO circumstances should compressed air cleaning be used.

Vacuum

Vacuum equipment intended for collecting asbestos dust and waste, or for normal cleaning operations, must be so designed that the asbestos dust cannot escape from the equipment back into the workplace. With portable equipment, the collecting unit is located in the area where the cleaning is taking place; therefore, the filter must be of such efficiency as to prevent the escape of asbestos dust.

High efficiency particulate air (HEPA) filtered vacuum cleaners or vacuum systems with appropriate asbestos filters that are in accordance with the American Conference of Governmental Industrial Hygienists (ACGIH) Ventilation Manual or the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI 29.2-1971 are required by regulations.

There are two forms of vacuum cleaning units that can be used in the friable asbestos-containing facilities. One is a portable industrial vacuum cleaner that uses filter bags. The filtered air is returned to the working environment. The other system is a central vacuum cleaning setup that consists of a central suction and filtration unit from which ducts run to those parts of the facility in which vacuum cleaning is necessary. The first type of vacuum cleaning is adequate where an extensive facility hygiene operation is used at irregular and infrequent intervals.

In facility hygiene operations, it is very likely that dust will re-enter the air while changing HEPA filters in vacuum cleaning devices. Recommended procedures for handling these types of asbestos-contaminated material include the following:

1. Appropriate respirators and protective clothing must be used during all exposures to the fine dust found in vacuum equipment.

2. HEPA filters for the vacuum system should be disposable.

3. Water will cause damage to an HEPA filter. If a filter is going to be exposed to moisture, a prefilter dryer is required.

4. Asbestos-contaminated filters should be sealed in airtight 6-mil plastic bags.

5. Warning labels must be affixed to plastic bags containing asbestos waste, and they shall state the following warning:

CAUTION
DO NOT OPEN
CONTAINS ASBESTOS FIBERS
AVOID CREATING DUST
BREATHING ASBESTOS DUST MAY CAUSE
SERIOUS BODILY HARM

6. Asbestos waste must be dumped in state-approved sanitary landfill sites.

In the event the internal parts of the vacuum system become contaminated (other than filters), the unit should be removed from the workplace, preferably into the open air. The operator, equipped with approved

respiratory protection and protective clothing, should remove the collected material and place it into an impermeable plastic bag. Any material spilled into the body of the equipment should be carefully collected, preferably by using another vacuum cleaner. However, if this is not possible, the material should be removed by hand using a damp cloth. The contaminated cloth should be disposed of along with the asbestos waste material.

Amended Water

Wet cleaning methods considerably reduce the possibility of dust reentrainment. Under most circumstances, the effectiveness of wetting can be greatly enhanced by a wetting agent (Ref 1), thus reducing the amount of water required in the cleaning operation. When a wetting agent is added, it alters the surface tension of water, and, as a result, dust can penetrate into a droplet rather than just adhering to its surface, and fine particles are more easily cemented into large agglomerates (Ref 3). Thus, dust capture capability can often be increased many times. Portable pump equipment has been employed to clean large surface areas; however, the treated water could possibly bypass certain types of seals within this type of equipment.

Manufacturers and distributors of commercially available wetting agents* are listed as follows:

Aquatrols Corp. of America
1400 Suckle Highway
Pennsauken, NJ 08110

Leffingwell Chemical Co.
Box 188
Brea, CA 92921

Occidental Chemical Co.
Institutional Division
Box 198
Lathrop, CA 95330

Rohm and Haas Co.
Ag. Chemical Dept.
Independence Mall
W. Philadelphia, PA 19105

Target Chemical Co.
1280 N. 10th St.
San Jose, CA 95112

Thompson-Hayward Chemical Co.
Box 2383
Kansas City, KS 66110

Vineland Chemical Co.
Box 745
Vineland, NJ 08360

Amended water may cause flash rusting on ferrous surfaces. In these cases, repainting is in order. The wet cleaning procedure requires, of course, some attention to electrical safety and other operational problems associated with water in the presence of machinery and equipment.

Care must be taken for properly disposing of the wastewater so that a hazard is not created through the drying of surfaces where asbestos fibers accumulated during the wash down. The invisible fibers carried by water droplets can become reentrained in the work space once the water has evaporated. Asbestos fibers would tend to concentrate in bilges, pipe trenches, and sumps unless these areas were thoroughly flushed of residue material.

---

*This information should not be construed as a product endorsement by the Navy.

Currently there is not an Environmental Protection Agency criterion on asbestos fibers released into receiving bodies, fresh water or saltwater.

Some of the problems concerning fiber reentrainment from dry surfaces could be reduced if the fibers being washed down bilges and trenches were collected in sumps or bilge collection points. The wastewater from these collection points should be disposed of in a trench within state-approved sanitary landfills. The trench should be covered with an asbestos-free material before the water evaporates.

Chemical-Impregnated Equipment

Chemically treated cleaning equipment can be used for routine cleaning but should not be considered for initial or annual facility hygiene operations. The processing of this type of cleaning equipment requires special handling, and the management at the processing establishment must be informed of the potential contamination of the equipment by asbestos fibers.

RECOMMENDATIONS

Further investigation into asbestos-containing products is required to clarify the extent of fiber release, conditions under which it occurs, and procedures for controlling its release.

With the vast diversity of existing asbestos-containing thermal insulation products and the difficulties of assessment in the field, a device for rapid detection and assessment should be developed as stricter regulations are implemented by OSHA. A standardized coding system for labeling asbestos-containing products or asbestos-free products should be considered for shore activities as well as a flagging system for Public Works Department maintenance files.

REFERENCES

1. Civil Engineering Laboratory. Management procedure for assessment of friable asbestos insulating material. Port Hueneme, Calif. (to be published)

2. The Asbestos Research Council. The cleaning of premises and plant in accordance with the Asbestos Regulations, Control and Safety Guide No. 9. London, Apr 1978.

3. G. Rajhaus and G. Bragg. Engineering aspects of asbestos dust control. Ann Arbor, Mich., Ann Arbor Sci. Pub., Inc., 1978.

APPENDIX E

PUBLIC WORKS CANADA, ONTARIO REGION

ASBESTOS PIPE COVERING REMOVAL AND MINOR WORK

SPEC NOTE: The intent of this Section is to provide a basis for project specification for partial or complete removal of material containing asbestos fibres, due to alterations or additions on Minor Works contracts. Pipe covering removal is described in this Section as most common requirement, but with proper adjustment this Section may be used to include removal of other items such as: boiler covering, encapsulated fireproofing, etc. Note that special procedure must be specified if asbestos pipe covering removal occurs above suspended ceilings. For large projects where asbestos removal, sealing or enclosure is required, use Section 13570.

1 Related Work Specified Elsewhere

.1 Pipe Recovering: Section [______]

2 Outline of Work

.1 [Where new piping connects to existing asbestos covered pipe, remove covering adjacent to area of connection.] [Remove entire asbestos pipe covering in [__________].]

3 Regulatory Agencies

.1 Comply with Federal, Provincial and local requirements pertaining to asbestos, provided that in any case of conflict among those requirements or with these specifications the more stringent requirements shall apply.

Restrictions

.1 Do not allow smoking, eating, drinking, gum or tobacco chewing or presence of ingestible material in work area.

.2 Do not allow entry to work area by unauthorized persons or by workers without protective clothing, eye protection, hard hat and respirators.

.3 Remove protective clothing and equipment and wash hands and face before leaving work area for any reason. Leave protective clothing and equipment in work area when not in use.

5 Material and Equipment

.1 Protective clothing, coveralls, hoods, gloves and boots: disposable type.

.2 Respirators: types acceptable to Labour Canada or Provincial Labour Department and suitable for asbestos exposure. If fitted with disposable filters only Type H, Type S or Type F filters shall be used or chemical cartridge approved for use in areas contaminated with asbestos dust and mist.

.3 Signs: Helvetica Medium type letters, upper case: "CAUTION, ASBESTOS HAZARD AREA" (25 mm), NO UNAUTHORIZED ENTRY" (19 mm)), "WEAR ASSIGNED PROTECTIVE EQUIPMENT (19 mm), "BREATHING ASBESTOS DUST MAY CAUSE SERIOUS BODILY HARM" (7 mm).

.4 Polyethylene: 0.15 mm thick minimum, in large sheet sizes to minimize joints.

.5 Tape: fiberglass type duct tape, self-adhering for wet and dry conditions.

.6 Sprayers: garden reservoir type, low velocity, capable of producing mist or fine spray, with hypodermic type nozzle for penetration through outer covering jackets.

.7 Wetting agent: 50% polyoxyethylene ester and 50% polyoxyethylene ether or other non-ionic surfactant proved to be effective in adding wetting of asbestos.

.8 Waste bags: 0.15 mm minimum thickness polyethylene.

.9 Waste receptors: 200 L capacity metal or fibre drums with tight lids, labelled in Helvetica Medium type letters, upper case: "CAUTION, CONTAINS ASBESTOS FIBRES" (25 mm) "DO NOT MISHANDLE" (19 mm), "BREATHING ASBESTOS DUST MAY CAUSE SERIOUS BODILY HARM" (7 mm).

.10 H.E.P.A. vacuum: (High Efficiency Particulate Absolute) filtered vacuum equipment with a filter system capable of collecting and retaining asbestos fibres at 99.97% efficiency for fibres 0.3 microns or larger.

6 Preparation

.1 Conduct preparation and removal of asbestos 84
after office hours. Close off work area. 86
SPEC NOTE: Delete .1 if building not occupied or 88
if occupants evacuated from areas adjacent to work 89
activities.

.2 Cover with polyethylene, floor and equipment 91
below and within a 4 m radius of asbestos to
be removed. Turn-up edges and tape all 92
joints.

.3 Shut down air circulation system within work 95
area.

.4 Clothe workers entering work area with 97
complete disposable protective clothing, eye 98
protection, hard hat and properly fitted
respirator. Wash respirator thoroughly and 99
install clean filters before each reuse.

.5 Instruct workers on necessary safety 101
procedures and protective measures. 102

.6 Install safety signs around restricted areas. 105

7 Removal

.1 Vacuum or wash pipe covering surfaces. 110

.2 Insert hypodermic nozzle through outer cover 112
of pipe and wet asbestos with water containing
1.25 kg/m^3 of wetting agent. 113

.3 Remove wetted asbestos material and covering 115
jackets in small sections and immediately 116
place in double waste bags. Maintain asbestos 117
in wet condition during removal operation.
Seal bags tightly. 118

.4 Clean surfaces exposed by asbestos removal 120
with wire brush and wet sponge. 121

.5 Immediately after removal of asbestos vacuum 123
all surfaces within work area, including
polyethylene covering, using H.E.P.A. filtered 124
vacuum equipment. If H.E.P.A. vacuum 125
equipment is not available, use cloths, mops
or sponges, dampened with water. Ensure that 126
surfaces are kept free of wet sludge which
after drying could release asbestos dust into
the atmosphere. Do not use vacuum equipment 127
other than H.E.P.A. equipment with high
efficiency filters.

7. Removal (Cont'd)

.6 Remove polyethylene floor covering, fold inward and place in double waste bags. Seal bags tightly.

.7 Place cloths, mops, sponges, rags, wire brushes, disposable filters and protective clothing in double waste bags. Seal bags tightly.

.8 Deposit filled waste bags in waste receptors. Seal waste receptors tightly with tapes.

.9 Repeat vacuuming of all surfaces within work area including waste receptors, reusable equipment used to perform the work, shoes, and soles of shoes.

.10 Thoroughly wash respirators, eye protection, hard hats, hands and face.

8 Disposal

.1 Deliver and deposit waste receptors in accordance with regulations set by environmental regulatory authorities.

*********************************END*********************************

<u>APPENDIX F</u>

PUBLIC WORKS CANADA

ASBESTOS ABATEMENT SPECIFICATION -

MAJOR WORK

(Third Draft)

SPEC NOTE: The intent of this Section is to 8
provide a basis for a project specification for
asbestos removal, sealing, or enclosure. These 10
procedures may be required separately or in
combination depending on the particular project.

SPEC NOTE: This Section is not intended to apply 12
to asbestos abatement during routine inspection and
maintenance, and during minor alteration work; for 13
abatement procedures applicable to these
activities, refer to Public Works Canada Property 14
Administration Branch Directive covering "Safe
Practices and Procedures for the Protection of 15
Workmen and Building Occupants During Routine
Inspection and Maintenance Services or During Minor
Alteration Work where Coatings or Coverings 16
Containing Asbestos Fibres are Encountered".

SPEC NOTE: Current regulations relate to 18
occupational exposures only and are not sufficient
for contracting purposes. Therefore it is 20
absolutely necessary to prepare explicit
specifications.

SPEC NOTE: General requirements applicable to the 22
project as a whole are not specified in this
section and must be specified in Division 1. These 24
include Description of Work, Work Schedule,
Contractors Use of Site, Security Program, Partial
Occupancy, Project Meetings, Site Signs and Notices 25
(warning signs), Photographs, Temporary Facilities
and Safety Measures (other than as specified in 26
this section), general building cleanup, and the
like. Review GMS/NMS Division 1 and modify to 27
suit. Similarly other work necessitated by 28
asbestos abatement but which can be performed in
clean areas or after decontamination of work areas 29
must be specified elsewhere (suspended ceilings,
re-fireproofing, painting, electrical and
mechanical work). IT IS RECOMMENDED THAT ASBESTOS 30
ABATEMENT, AND RELATED WORK SUCH AS THAT MENTIONED
ABOVE, BE CARRIED OUT UNDER A SINGLE CONTRACT.
THIS PERMITS CONTROL OVER THE PROJECT AND 31
FACILITATES SAFE PRACTICE.

SPEC NOTE: The wording of this Section must be 33
edited to suit the particular project. Wording 34
must be added or deleted in accordance with the
normal editing process; square brackets indicate 35
that a choice of wording must be made, or that
missing information must be provided.

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PART 1 - GENERAL

1.1 Outline of Work

SPEC NOTE: Identify precisely, preferably by means of drawings, the extent of removal, sealing ~~encapsulation~~, and enclosure of spray or trowel applied asbestos-containing material.

.1 Remove as specified all spray or trowel applied asbestos-containing material located [as indicated on drawings] [at the site] [______]except where removal is considered impracticable by the Engineer.

.2 Seal as specified all spray or trowel applied asbestos-containing material located [as indicated on drawings] [at the site] [where removal is considered by the Engineer to be impracticable [______].

.3 Enclose as specified all sprayed-on asbestos-containing material located [as indicated on drawings] [at the site] [______].

1.2 Definitions

.1 HEPA vacuum: High Efficiency Particulate Absolute filtered vacuum equipment acceptable to Health and Welfare Canada.

.2 Polyethylene sheeting sealed with tape: polyethylene sheeting of thickness specified sealed with tape along all edges, around penetrating objects, over cuts and tears, and elsewhere as required to provide a continuous polyethylene membrane to protect underlying surfaces from water damage or damage by sealants, and to prevent escape of asbestos fibres through the sheeting into a clean area.

.3 Authorized visitor: the Engineer or his approved representative, [______]and persons representing regulatory agencies.

.4 Work Areas: where the actual [removal] [and] [sealing] [and] [enclosure] of spray or trowel applied asbestos containing materials take[s] place.

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1.3 Regulatory Agencies

.1 Comply with Federal, Provincial, and local requirements pertaining to asbestos, provided that in any case of conflict among those requirements or with these specifications the more stringent requirement shall apply.

1.4 Submittals

.1 Before commencing work:

.1 Obtain from the appropriate agency and submit to the Engineer all necessary permits for transporting and disposal of asbestos waste.

SPEC NOTE: Delete 1.4.1.1 if removal does not apply.

.2 Submit proof satisfactory to Engineer that all employees have had instruction on the hazards of asbestos exposure, on respirator use, on dress, use of showers, entry and exit from work areas, and all aspects of work procedures and protective measures.

.3 Submit layout of proposed enclosures for approval.

SPEC NOTE: Use 1.4.1.3 if the Contractor is responsible for layout of enclosures. It is preferable, however, to define enclosures in the contract.

.4 Submit documentation including test results for sealer proposed for use.

SPEC NOTE: Delete 1.4.1.4 if sealing does not apply.

1.5 Existing Conditions

.1 Results of tests of asbestos-containing materials taken from surfaces within the scope of this project are [available for inspection at [______]] [bound into this specification at the end of this section]. These are for general information only and are not necessarily representative of all asbestos containing materials contained within the scope of this project.

1.6 worker Protection

.1 Instructions: Before commencing work instruct workers in use of respirators, dress, showers, entry and exit from work areas, and all aspects of work procedures and protective measures.

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1.6 Worker Protection (Cont'd)

.2 Respirators: Provide workers with personally issued and marked respiratory equipment acceptable to Labour Canada or provincial labour department as suitable for the asbestos exposure in the work area. If disposable type filters are used provide sufficient filters so that workers can install new filters following disposal of used filters and before reentering contaminated areas.

.3 Protective Clothing: Provide workers with full body disposable type coveralls. Provide other body protection required under applicable safety regulations.

.4 Each worker shall:

.1 Remove street clothes in the clean change room and put on respirator with new filters, disposable coveralls and head covers before entering the equipment and access areas or the work area.

.2 Remove gross contamination from clothing before leaving the work area then proceed to the equipment and access area and remove all clothing except respirators. Still wearing the respirator proceed naked to the showers. Clean the outside of the respirator with soap and water while showering; remove the respirator; remove filters and wet them and dispose of filters in the container provided for the purpose; and wash and rinse the inside of the respirator. When not in use in the work area, store work footwear in the equipment and access area. Upon completion of asbestos abatement, dispose of footwear as contaminated waste or clean thoroughly inside and out using soap and water before removing from work area or from equipment and access area. Place contaminated worksuits in receptacles for disposal with other asbestos contaiminated materials.

.3 Following showering and drying off, proceed to the clean change room and dress in street clothes at the end of each day's work, or in clean coveralls before eating, smoking, drinking, or reentering the work area.

.4 Enter the unloading room from outside dressed in clean coveralls to remove drums and equipment from the holding room of the drum and equipment decontamination enclosure system. No worker shall use this system as a means to leave or enter the work area.

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1.6 worker Protection (Cont'd)

.5 Workers shall not eat, drink, smoke or chew gum or tobacco at the work site excpet in the established clean room.

.6 Workers shall be fully protected with respirators and protective clothing during preparation of system of enclosures prior to commencing actual asbestos abatement.

1.7 Visitor Protection

.1 Provide protection clothing and approved respirators to authorized visitors to work areas.

.2 Instruct authorized visitors in the use of protective clothing and respirators.

.3 Instruct authorized visitors in proper procedures to be followed in entering into and exiting from work areas.

1.8 Notification

.1 Not later than [ten] days before commencing work on this project notify the following in writing.
  .1 The appropriate Regional or Zone Director of the Medical Services Branch, Health and Welfare Canada.
  .2 The Regional Office of Labour Canada.
  .3 The Provincial Department of Labour.

SPEC NOTE: Include notification of all agencies with involvement in asbestos abatement.

PART 2 - PRODUCTS

2.1 Materials

SPEC NOTE: Include materials required for enclosing asbestos surfaces if enclosure is specified.

.1 Polyethylene: in 0.15 mm minimum thickness unless otherwise specified; in sheet size to minimize joints.

.2 Tape: fiberglass type duct tape suitable for sealing polyethylene under both wet conditions using amended water, and dry conditions.

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2.1 Materials (Cont'd)

.3 Wetting agent: 50% polyoxyethylene ester and 50% polyoxyethylene ether mixed with water in a concentration to provide adequate penetration.

.4 Asbestos waste receptors: 200 L capacity metal or fibre drums with tightly fitting lids and 0.15 mm minimum thickness sealable polyethylene liners. Drums shall be labelled in accordance with Occupational Safety and Health Administration, United States Department of Labour, (OSHA) Asbestos Regulations (29 CFR 1910.1001). Labelling shall be in both official languages.

.5 Sealers: [bridging] [penetrating] type approved by the [Dominion Fire Commissioner] having the following characteristics [______].

SPEC NOTE: Specify particular characteristics where a more restrictive requirement applies. Sealers on the DFC list have been examined principally from the point of view of fire; some, such as latex paint, have extremely limited use for asbestos control. There are currently ASTM and CGSB committees working on standards for asbestos sealers, but as of 20 November 1980, no standards exist. Thus it is difficult to specify a sealer for asbestos control with confidence. EPA have available useful information on sealers, based on tests performed for them by Battelle Columbus Laboratories. This information should be studied before specifying a sealer.

.6 Sprayed fireproofing: ULC labelled and listed asbestos-free mineral fibre to provide the degree of fire or thermal protection required by current NBC standards.

SPEC NOTE: Use 2.1.6 when repairs are required to existing sprayed-on material prior to sealing or enclosing. When complete removal of existing sprayed-on material is specified, use GMS/NMS Section 09841 "Sprayed Fireproofing" to specify replacement material.

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PART 3 - EXECUTION

3.1 Preparation

SPEC NOTE: If decontamination systems enclosures, and barrier systems, are not indicated on drawings, the Contractor should be requested to provide a proposed layout under 1.4.3 of this section.

.1 Work Areas:

.1 Isolate air handling and ventilation systems to prevent contamination and fibre dispersal to other areas of the building during the work phase.

.2 Preclean moveable objects [and carpeting] within the proposed work areas using HEPA vacuum and remove such objects from work areas to a temporary location in [______].

SPEC NOTE: Prior to commencing work moveable objects and carpeting should be removed from work areas. Use 3.1.1.2 if Contractor is responsible for this work. If any moveable object is to remain in work areas indicate, and specify protection, under 3.1.1.3.

.3 Preclean fixed casework, plant, and equipment within the proposed work areas, using HEPA vacuum and cover with polyethylene sheeting sealed with tape.

.4 Clean the proposed work areas using, where practicable, HEPA vacuum cleaning equipment. If not practicable, use a wet cleaning method. Do not use methods that raise dust, such as dry sweeping, or vacuuming using other than HEPA vacuum equipment.

.5 Seal off all openings such as corridors, doorways, windows, skylights, ducts, grilles, and diffusers, with polyethylene sheeting sealed with tape.

.6 Cover floor and wall surfaces with polyethylene sheeting sealed with tape. [Use two layers of polyethylene on floors]. Cover floors first so that polyethylene extends at least 300 mm up walls then cover walls to overlap floor sheeting.

.7 Build [double] barriers of polyethylene sheeting at all entrances to and exits from the work areas so that work areas are always closed off by one barrier when workers enter or exit.

.8 After work area isolation remove heating, ventilating, and air conditioning filters, pack in sealed plastic bags 0.15 mm minimum thickness and treat as contaminated asbestos waste. Remove ceiling mounted objects such as

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3.1 Preparation (Cont'd)

.1 (Cont'd)

.8 (Cont'd)
lights, partitions, other fixtures not
previously sealed off, and other objects that 280
interfere with asbestos removal, as directed
by Engineer. Use localized water spraying 281
during fixture removal to reduce fibre
dispersal.

.9 Maintain emergency and fire exits from 283
the work areas, or establish alternative exits
satisfactory to the Dominion Fire Commissioner 284
and Provincial Fire Marshall.

.10 Provide 24 volt safety lighting where 286
excessive application of water is required for
wetting asbestos containing materials. Ensure 288
safe installation of electrical lines and
equipment.

.11 After preparation of work areas and 290
decontamination enclosure systems remove
ceiling [panels] [and] [tiles] within the work 291
areas progressively and carefully, [clean
using HEPA vacuum and damp sponge, wrap clean 292
panels in 0.10 mm minimum thickness
polyethylene, and store in building as
directed by Engineer] [and dispose of as 293
contaminated waste]. Clean "T" grid 294
suspension system within the work areas using
wet sponge, disconnect grid from hangers,
[wrap grid members in 0.10 mm minimum 295
thickness polyethylene] and store in building
as directed by Engineer.

SPEC NOTE: When suspended ceiling panels or grids 297
must be removed include under this Section, rather
than under Demolition, to ensure that ceiling 298
removal is done under safe conditions.

.12 After preparation of work areas and 300
decontamination enclosure systems remove
plaster ceilings, including lath, furring, 301
channels, hangers, wires, clips, and dispose
of as contaminated waste in the specified 302
drums. Spray ceiling debris and the immediate 303
work area with amended water to reduce dust,
as the work progresses.

SPEC NOTE: When plaster ceilings must be removed, 305
include under this section, rather than under 306
Demolition, to ensure that ceiling removal is done
under safe conditions.

.2 Workers Decontamination Enclosure System: 309

.1 The worker decontamination enclosure 311
system shall comprise an equipment and access
room, a shower room, and a clean room, as 312
follows:

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3.1 Preparation (Cont'd)

.2 (Cont'd)

.2 Equipment and access room: Build an 314
equipment and access room between the shower
room and the work areas, with two doorways, 315
one to the shower room and one to the work
areas. Install portable toilet, waste 316
receptor, and storage facilities for workers'
shoes and any protective clothing to be reworn
in work areas. The equipment and access room 318
shall be large enought to accommodate
specified facilities, any other equipment
needed, and at least one worker allowing him 319
sufficient space to undress comfortably.

.3 Shower room: Build a shower room between 321
the clean room and the equipment and access
room, with two doorways, one to the clean room 322
and one to the equipment and access room.
Provide one shower for every five workers. 323
Provide a constant supply of hot and cold or 324
warm water. [A cold water source is available 325
at [______]]. [A hot water source is 326
available at [______]]. Drains to common 327
sewers are available at [______]. Provide 328
piping and connect to water sources and
drains. Pump waste water through a 5 329
micrometre filter system acceptable to the
Engineer before directing into drains.
Provide soap, clean towels and appropriate 330
containers for disposal of used respirator
filters.

.4 Clean room: Build a clean room between 332
the shower room and clean areas outside of
enclosures, with two doorways, one to outside 333
of the enclosures and one to the shower room.
Provide lockers for workers street clothes and 334
personnal belongings. Provide storage for 335
clean protective clothing and respiratory
equipment. Install a mirror to permit workers 336
to fit respiratory equipment properly, and
sufficient hangers and hooks.

.3 Drum and Equipment Decontamination Enclosure 338
System: 339

.1 The drum and equipment decontamination 341
enclosure system shall comprise a staging area
within the work area, a washroom, a holding 342
room, and an unloading room. The purpose of 343
this system is to provide a means to
decontaminate drums, scaffolding, material
containers, vacuum and spray equipment, and 344
other tools and equipment for which the worker
decontamination system is not suitable.

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3.1 Preparation (Cont'd)

.3 (Cont'd)

.2 Staging area: Build a staging area in the work area for gross removal of dust and debris from drums and equipment, labelling and sealing of drums, and temporary storage pending removal to washroom. The staging area shall have a doorway to the washroom.

.3 Washroom: Build a washroom between the staging area and the holding room with two doorways, one to the staging area and one to the holding room. Provide high pressure low volume sprays for washing of drums and equipment. Pump waste water through 5 micrometre filter system before directing into drains. Provide piping and connect to water sources and drains.

.4 Holding room: Build a holding room between the washroom and the unloading room, with two doorways, one to the washroom and one to the unloading room. The holding room shall be of sufficient size to accommodate at least two barrels and the largest item of equipment used.

.5 Unloading room: build a unloading room between the holding room and the outside, with two doorways, one to the holding room and one to the outside.

.4 Construction of Decontamination Enclosures:

.1 Build suitable framing for enclosures [or use existing rooms where convenient], and line with polyethylene sheeting sealed with tape. [Use two layers of polyethylene on floors].

.2 Build [double] barriers of polyethylene at all doorways so that when drums and equipment are moved through a doorway, one of the [two] barriers comprising the doorway always remains closed.

.5 Separation of Work Areas from Occupied Areas.

.1 Separate parts of the building required to remain in use [as shown on drawings] from parts of the building used for asbestos abatement by means of an airtight barrier system constructed as follows.

.2 Build suitable floor to ceiling lumber or metal stud framing, cover with polyethylene sheeting sealed with tape, and apply 9 mm minimum thickness plywood. Seal all joints between plywood sheets and between plywood and adjacent materials with bridging sealer ~~encapsulant~~, to create an airtight barrier.

.3 Cover plywood barrier with polyethylene sealed with tape, as specified for work areas.

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3.1 Preparation (Cont'd)

.5 (Cont'd)

SPEC NOTE: Use 3.1.5 where it is necessary to carry out asbestos abatement procedures in a building required to remain in use.

.6 Maintenance of Enclosures:
  .1 Maintain enclosures in tidy condition.
  .2 Ensure that barriers and polyethyene linings are effectively sealed and taped. Repair damaged barriers and remedy defects immediately upon discovery.
  .3 Visually inspect enclosures at the beginning of each working period.
  .4 Use smoke methods to test effectiveness of barriers when directed by Engineer.

SPEC NOTE: The polyethylene enclosed areas should be indicated on drawings or otherwise defined in the contact. Alternatively the Contractor should be requested to indicate proposed layout under paragraph 1.4.1.3 of this section.

.7 Asbestos Abatement work shall not commence until:
  .1 Arrangements have been made for disposal of waste.
  .2 For wet stripping techniques arrangements have been made for containing, filtering, and disposal of waste water.
  .3 Work areas and decontamination enclosures [and parts of the building required to remain in use] are effectively segregated.
  .4 Tools, equipment and materials waste receptors are on hand.
  .5 Arrangements have been made for building security.
  .6 All other preparatory steps have been taken.

3.2 Asbestos Removal

.1 Before removing asbestos:
  .1 Prepare site.
  .2 Spray asbestos material with water containing the specified wetting agent, using airless spray equipment. Saturate the asbestos material to prevent release of airborne fibres. Spray the asbestos material repeatedly during work process to maintain saturation and to minimize asbestos fibre dispersion.

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3.2 Asbestos Removal (Cont'd)

.2 Remove the saturated asbestos material in 442
small sections. Before beginning the next 443
section pack the material in sealable plastic
bags 0.15 mm minimum thickness and place in 444
labelled drums for transport.

.3 Seal filled drums. Clean external surfaces 447
thoroughly by wet sponging. Remove from 448
immediate working area to staging area, wash
drums thoroughly in decontamination washroom,
and store in holding room pending removal to 449
unloading room and outside. Ensure that drums 450
are removed from the holding area by workers
who have entered from uncontaminated areas
dressed in clean coveralls. 451

.4 After completion of stripping work, all 453
surfaces from which asbestos has been removed
shall be wire brushed and wet-sponged to 454
remove all visible material. During this work 455
the surfaces shall be kept wet.

.5 Where the Engineer decides removal of 457
asbestos-containing material is impossible due
to obstructions such as structural members or 458
major service elements, and provides a written
direction, encapsulate the material as 459
follows:
.1 [Apply bridging type sealer to provider 461
[0.635] mm minimum dry film thickness over
sprayed asbestos surfaces. Apply using 463
airless spray equipment to avoid blowing off
fibres. Use different colour for each coat]. 464
Use [______]colour for final coat. [Apply 466
penetrating type sealer to penetrate existing
sprayed asbestos surfaces to uniform depth of
[25] mm minimum]. [Apply penetrating type 467
sealer to penetrate existing sprayed asbestos
surfaces uniformly to substrate].

.6 After wire brushing and wet sponging to remove 469
visible asbestos, [and after sealing asbestos-
containing material impossible to remove], wet 470
clean the entire work area including the 471
equipment and access area, and equipment used
in the process. After a 24 hour period to 472
allow for dust settling, wet clean these areas
and objects again. During this settling 473
period no entry, activity, or ventilation will
be permitted. After a second 24 hour period 474
under the same conditions clean these areas
and objects again using HEPA vacuum followed 475
by wet cleaning.

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3.3 Asbestos Sealing

.1 Before sealing asbestos: 479
.1 Prepare site. 482
.2 Vacuum surfaces in work areas except 484
those to be sealed, using HEPA vacuum to
remove all loose debris and dust particles. 485
.3 Repair damaged and missing areas of 487
existing sprayed asbestos to obtain a suitable
base for sealing and to restore continuity of 488
fireproofing. Use the specified asbestos-free 489
fireproofing material. Prepare surfaces and 490
apply fireproofing in accordance with
manufacturer's recommendations.
.4 Remove loose asbestos and pack in 492
sealable plastic bags 0.15 mm minimum
thickness and place in labelled drums for 493
transport.
.5 Seal filled drums. Clean external 496
surfaces thoroughly by wet sponging. Remove 497
from immediate working area to staging area,
wash drums thoroughly in decontamination
washroom, and store in holding room pending 498
removal to unloading room and outside. Ensure 499
that drums are removed from the holding area
by workers who have entered from
uncontaminated areas dressed in clean 500
coveralls.

.2 [Apply bridging type sealer to provide [0.635] 502
mm minimum dry film thickness over sprayed
asbestos surfaces. Apply using airless spray 504
equipment to avoid blowing off fibres. Use 505
different colour for each coat]. Use 506
[______]colour for final coat. [Apply 507
penetrating type sealer to penetrate existing
sprayed asbestos surfaces to uniform depth of
[25] mm minimum]. [Apply penetrating type 508
sealer to penetrate existing sprayed asbestos
surfaces uniformly to substrate].

.3 After sealing asbestos surfaces wet clean the 510
entire work area including the equipment and
access area, and equipment used in the 511
process. After a 24 hour period to allow for 512
dust settling wet clean these areas and
objects again. During this settling period no 513
entry, activity, or ventilation will be
permitted. After a second 24 hour period 514
under the same conditions clean these areas
and objects again using HEPA vacuum followed 515
by wet cleaning.

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3.3 Asbestos Sealing (Cont'd)

.4 Install warning signs in both official 517
languages in 25 mm sans serif letters worded
as follows: WARNING-SEALED ASBESTOS. 518
[Install signs at locations indicated on 519
drawings]. A total of [______]signs will be 520
required.

3.4 Asbestos Enclosure

.1 Before enclosing asbestos: 524
.1 Prepare site. 526
.2 Vacuum all surfaces in work areas, except 528
asbestos surfaces, using HEPA vacuum equipment
to remove all loose debris and dust particles. 529
.3 Spray areas to be disturbed while 531
securing hangers and other fixing devices.
Use water containing the specified wetting 532
agent. Keep asbestos material damp to prevent 533
release of airborne fibres.
.4 Remove loose asbestos and pack in 535
sealable plastic bags 0.15 mm minimum
thickness and place in labelled drums for 536
transport.
.5 Seal filled drums. Clean external 539
surfaces thoroughly by wet sponging. Remove 540
from immediate working area to area set aside
for storage in the equipment and access area.
Ensure that drums are removed from the 541
equipment and access area by workers who have
entered from uncontaminated areas dressed in 542
clean coveralls.

.2 After installation of hangers and other fixing 544
devices and before enclosing asbestos, repair 545
damaged and missing areas of existing sprayed
on material using the specified asbestos-free 546
fireproofing material. Prepare surfaces and 547
apply fireproofing or thermal insulation in
accordance with manufacturer's
recommendations.

.3 Enclose asbestos surfaces as follows: 549
SPEC NOTE: There are so many ways to enclose 551
asbestos surfaces that it is impossible to include 552
a useful specification here. Specify methods to 553
suit the particular situation. (Describe one type) 554

.4 After enclosing asbestos surfaces wet clean 556
the entire work area including equipment and
access area, and equipment used in the 557
process. After a 24 hour period to allow for 558
dust settling wet clean these areas and
objects again. During this settling period no 559

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3.4 Asbestos Enclosure (Cont'd)

.4 (Cont'd)
entry, activity, or ventilation will be
permitted. After a second 24 hour period 560
under the same conditions clean these areas
and objects again using HEPA vacuum followed 561
by wet cleaning.

.5 Install warning signs [at each access] [at 563
locations directed by Engineer] in both
official languages in 25 mm san serif letters 564
worded as follows: WARNING; ENCLOSED ASBESTOS.

3.5 Cleanup

.1 The areas shall be fogged with water. Twenty- 569
four hours after fogging, air samples shall be
taken in work, access and equipment, areas.
Air circulatory fans of sufficient size and 570
number shall be used to simulate occupant
activity. Polyethylene seals shall be removed 571
when air sampling shows that asbestos levels
on both sides of seals do not exceed 0.10 572
fibres/cc as determined by the membrane filter
method at 400-500X magnification phase
contrast illumination, as described in NIOSH 573
technical report 70-127 or equivalent.

.2 Place polyethylene seals, tape, cleaning 575
material, clothing, and other contaminated
waste in plastic bags and sealed labelled
drums for transport. 576

.3 Work areas, equipment and access area, 578
washing/showering room, and other enclosures
that may be contaminated shall be included in 579
the clean-up.

.4 Sealed drums and all equipment used in the 581
work shall be included in the cleanup and
shall be removed from work areas, via the drum 582
and equipment decontamination enclosure
system, at an appropriate time in the cleaning
sequence.

.5 A final check shall be carried out to ensure 584
that no dust or debris remains on surfaces as 585
a result of dismantling operations and air-
monitoring shall be carried out again to 586
ensure that asbestos levels in the building do
not exceed 0.10 fibres/cc . Repeat cleaning 587
and sampling until levels meet this criterion.

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3.5 Cleanup (Cont'd)

.6 As the work progresses, and to prevent exceeding available storage capacity on site, remove sealed and labelled drums containing asbestos waste and dispose of to authorized disposal area in accordance with requirements of disposal authority.

SPEC NOTE: Specify major restoration work such as respraying of fireproofing, and new suspended ceilings, in other sections of the specification.

3.6 Reestablishment of Objects and Systems

.1 When cleanup is complete:
.1 Reestablish objects moved to temporary locations in the course of the work, in their proper positions.
.2 Re-secure mounted objects removed in the course of the work in their former positions.

.2 Reestablish mechanical and electrical systems in proper working order.

.3 Repair or replace objects damaged in the course of the work, as directed by Engineer.

3.7 Air Monitoring

.1 From commencement of work until completion of cleaning operations air samples will be taken by the Engineer both inside and outside of work area enclosures in accordance with Health and Welfare Canada recommendations.

.2 If air monitoring shows that areas outside work area enclosures are contaminated these areas shall be enclosed, maintained and cleaned, in the same manner as that applicable to work areas.

.3 The results of air monitoring inside work areas will be used to establish the type of respirators to be worn.

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***********************************END*************************************

APPENDIX G

METROPOLITAN TORONTO SCHOOL BOARD

DRAFT REMOVAL SPECIFICATIONS

1. GENERAL

1. Conform to General Conditions Form - as amended by the Supplementary General Conditions.

   Remarks: Insert applicable document.

2. SCOPE OF WORK

1. Work Included:

   a) Removal of spray or trowel applied asbestos coatings or finishes.

   b) Provision of isolation of work areas.

   c) Provision of decontamination areas.

   d) Disposal of asbestos debris.

   e) Air monitoring.

   f) Painting surfaces which have been cleared of asbestos.

2. Work Not Included:

   a) Asbestos containment.

   Remarks: This work is specified elsewhere.

   b) Restoration of protective membranes removed under the terms of this contract.

3. GENERAL REQUIREMENTS

1. All work shall be governed by applicable municipal and provincial by-laws.

   Remarks: OSHA and EPA regulations (U.S.A.) may be cited as guidance documents.

2. Contractor is required to furnish documentation of successful performance in asbestos removal. Documentation shall include name and address of purchaser of service, location of work performed, and a record of air monitoring for asbestos.

3. The contractor shall furnish proof that employees have had instruction on the dangers of asbestos exposure, on respirator use, decontamination, and applicable regulations.

4. The Architect reserves the right to order immediate cessation of all work, should he discover that work practices are violating pertinent regulations or are endangering workers.

5. Removal of asbestos shall be through application of wet removal techniques. Dry removal of friable asbestos will not be permitted.

   Remarks: Vacuuming skills are being perfected and may be approved in writing upon application.

6. A warning sign shall be installed in or at the entrance to the hazardous work area.

4.
DECONTAMINATION

1. Work Clothes

Contractor shall provide and ensure that the following work clothes are worn by workmen on site throughout execution of this contract

a) Full body coveralls of disposable type.

b) Disposable head, boot covers and gloves.

Remarks to specifier: Wear hard hat when applicable.

c) Eye protection.

d) Respiratory protection.

2. Decontamination Areas

Contractor shall provide an adequate decontamination area consisting of a serial arrangement of connected rooms or enclosed spaces.

Contractor shall ensure that all workmen, without exception, pass through this decontamination area for entry into and exit from the work area for any purpose.

3. The decontamination areas shall be set up as follows:

a) Outside room (clean area) - workmen shall leave street clothes here and dress in clean working clothes (disposable overalls). Respiratory protection shall be picked up here.

Workers enter this room either from outside dressed in street clothes or from work area through shower room.

Note: No asbestos contaminated items shall enter this room.

b) Shower room - this room shall be located between clean area and work area. It shall be used for transit by cleanly dressed workmen entering the work area, or by workmen headed for showers from the contaminated area.

Remarks to specifier: Temporary shower stalls shall be provided by the contractor.

c) Equipment room (contaminated area) - this room shall be used for storing work equipment, footwear and work clothing.

d) Work area - this area shall be separated from the equipment by polyethylene barriers. In general, partitions shall be framed with 2 x 4 studs and 6 mill polyethelene plastic sheets applied to both sides of stud partitions.

Remarks to specifier: Temporary toilets should be installed in this area.

4. DECONTAMINATION (Cont'd)

Decontamination Sequence

4. Worker must enter outside room and remove clothing, put on clean coveralls and respirator, and pass through into the equipment room (contaminated area). Here any additional clothing required by the worker shall be put on. Work equipment and tools shall be obtained here.

Drinking water and disposable cups shal be supplied here.

5. Worker shall then proceed to work area.

6. Before leaving the work area, the worker shall remove all gross contamination and debris from the overalls.

7. The worker shall proceed to equipment room and shall remove all clothing except respiratory protection equipment. Extra work clothing may be stored in contaminated end of the unit. Disposable coveralls are placed in a bag for disposal with other material. The worker then proceeds into the shower room. Respiratory protection equipment shall be removed last to prevent inhalation of fibers during removal of contaminated clothing.

Workers shall assist each other. Contractor to provide vacuum cleaner with disposable filter bags - for personal use.

8. After showering, the worker shall proceed to the clean room where he will dress in either new coveralls for another entry or street clothes if leaving.

9. Respirators shall be picked up, cleaned and wrapped by protected workers in a separate area by washing. The respirators must be brought to the clean room by an outside worker.

Note: Temporary showers, soap, towels shall be provided by the Contractor.

5. WORK PREPARATION

1. The following items or furnishings within the work areas shall be removed prior to commencement of work:

   a) Loose furniture.
   b) Drapes and carpets.
   c) Lay-in ceiling tiles, including T-bar grid.
   d) Light fixtures.

Specify: Responsibility for this work.

2. All items removed and scheduled to be re-installed shall be stored and kept safe until required.

3. Equipment or furnishings which cannot be removed shall be sealed with 6 mil polyethylene sheeting.

4. All openings within the work area shall be sealed with 6 mil polyethylene plastic, held in place with suitable tape. Similarly seal joints between sheets. Such openings shall in general encompass ducts, vents, grilles, floor drains, skylights, windows, doors, electrical ducts and boxes.

5. WORK PREPARATION (Cont'd)

5. Wall and floor surfaces shall be protected with continuous sheets of similar plastic. Joints between wall and floor sheets shall be tape sealed.

6. The ventilation and forced air heating system of the work areas shall be isolated and turned off.

6. ASBESTOS REMOVAL

1. The Architect's approval of all proposed isolation barriers and removal procedures is required. No stripping of asbestos will be permitted until the Architect has inspected the work site and the approval to proceed with the work has been given in writing.

2. No asbestos shall be removed until the fibres have been sprayed with water solution containing an additive to enhance penetration. This additive (or wetting agent) shall be a mixture of 50% polyethylene ester and 50% polyoxythylene ether at a concentration of 1 ounce per 5 gallons of water.

3. A fine spray of this solution shall be applied to prevent fiber disturbance preceding the removal of the asbestos material. The asbestos membrane shall be completely saturated to prevent emission of airborne fibers.

4. Asbestos shall only be removed by hand scraping. Power operated blowers will not be permitted.

5. Removed asbestos fibres shall immediately be collected in 6 mil plastic bags and placed in rigid containers having sealable lids. Notes: Fallen debris must be collected at end of days or shift work. Containers shall be kept sealed at all times.

   Remarks to specifier: Suggest 55 gallon drums.

6. Fallen asbestos debris shall again be sprayed with amended water before collecting and placing in bags.

7. Packed containers shall be sealed and labelled before leaving the contaminated area.

   Remarks to specifier: Apply hazard sticker

8. Following removal, the entire area shall be wet cleaned. After a 24 hour period to allow for dust settling, the entire area shall be wet cleaned again. During this settling period, no entry, activity, or ventilation will be allowed.

9. 24 hours after the second cleaning, all surfaces in the entire work area shall be vacuumed and wet mopped.

10. All polyethylene material, tape, cleaning material, and clothing shall be placed in plastic-lined drums, sealed and labelled as described above for the asbestos waste material.

REMARKS TO SPECIFIER

6.
ASBESTOS
REMOVAL
(Cont'd)

11. All equipment shall be cleaned of asbestos material prior to leaving the work area.

7.
AIR
MONITORING

1. Throughout the removal and cleaning operations, air sample monitoring shall be conducted to ensure that the Contractor is complying with all codes, regulations and ordinances. The air monitoring technician and his equipment shall be subject to approval of the Architect.

2. Air monitoring shall be performed to provide the following samples during the period of asbestos removal:

a)

Area to be sampled	Number of samples	Minimum sample volume in litres
Work area	4	60
Outside work area barriers	2	120

Samples will be taken after the actual removal operation has begun.

b) After the second (final) cleaning operation, the following tests shall be performed:

i. A complete visual inspection.

ii. Two air samples within 48 hours after completion of all cleaning work.

Minimum volume of air sample shall be 240 litres.

4. The cleaning operations shall be repeated if:

a) A visual inspection detects asbestos remnant still clinging to the sub strate, and

b) Air sample tests prove fibre count above acceptable limits.

Specify accepted fibre count per cm3 air.

8. ASBESTOS DISPOSAL

1. All asbestos materials and miscellaneous debris in sealed drums shall be transported to the predesignated disposal site in accordance with the guidelines of governmental agencies having jurisdiction.

2. The bags may be dumped from the drums into the burial site. The drums may be reused. However, if a bag is broken or damaged, the entire drum should be buried.

9. ENCAPSULATION OF RESIDUE FIBRES

All surfaces cleared of asbestos shall be painted with two coats of Latex paint.

This work is optional. Purpose: to encapsulate any fibre which has not been removed.

10. COMPLETION

1. Upon instructions by the Architect, Contractor shall remove all temporary partitions, screens, facilities and equipment.

Specify if part of asbestos removal contract.

2. Previously removed furniture, owner's equipment, ceilings or light fixtures will be re-installed by owner's forces.

APPENDIX H

FOUNDATION OF THE WALL AND CEILING INDUSTRY GUIDE SPECIFICATIONS FOR THE ABATEMENT OF ASBESTOS RELEASE FROM SPRAY- OR TROWEL-APPLIED MATERIALS IN BUILDINGS AND OTHER STRUCTURES

Guide Specifications For The Abatement of Asbestos Release from Spray- Or Trowel-Applied Materials In Buildings And Other Structures.

A GUIDANCE DOCUMENT ON ASBESTOS-CONTAINING
BUILDING MATERIALS IN STRUCTURES.
DECEMBER, 1981

Published by:
THE FOUNDATION of the WALL & CEILING
INDUSTRY
25 K St. N.E.
WASHINGTON, D.C. 20002 U.S.A.

For the Users of This Document:

This guide specification has not been officially adopted or "approved" by the public agencies participating in its development.

Under the sponsorship of the Foundation of Wall & Ceiling Industry, an Ad Hoc Task Group of Technical Subcommittee No. 4 of the Association of the Wall/Ceiling Industries-International, Inc. developed this document.

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Early drafts of this guide specification have been circulated, for comment, to persons and organizations too numerous to list. Their contributions are gratefully acknowledged.

These guide specifications were prepared by the above listed Ad Hoc task group, to assist architects, engineers, and building owners in preparing project specifications and contracts for asbestos abatement work.

Although the authors have made every attempt to insure that these guide specifications reflect the best technology for asbestos abatement which is currently available, they do not claim that use of the specifications will guarantee a risk-free, successful abatement job, and cannot take responsibility for any work done using these specifications. Technology relating to asbestos abatement is changing rapidly and more advanced techniques may become available. The user of this document should keep abreast of new developments in techniques, equipment and legal requirements through consulting appropriate technical and legal publications.

Additional comments and suggestions for the improvement of this document are welcomed and encouraged. Such comments may be directed to Gene Erwin, Technical Director, AWCI, 25 K St. N.E., Washington, D.C. 20002, or to any member of AWCI Technical Subcommittee No. 9 Asbestos Abatement:

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SPECIFICATIONS

1.6.2 Provide workers with personally issued and marked respiratory equipment approved by [Labour Canada] [Provincial Labour Dept.] [Provincial Department of ____________] [NIOSH and MSHA] and suitable for the asbestos exposure level in the work area according to [OSHA Standard 29 CFR 1910.1001] [applicable standard]. Where respirators with disposable filter are employed, provide sufficient filters for replacement as required by the worker or applicable regulation.

1.6.3 Provide authorized visitors with suitable respirators with new filters or cartridges whenever they are required to enter the work area, to a maximum of [______] per day.

1.6.4 Provide workers with sufficient sets of protective full body clothing. Such clothing shall consist of full body coveralls and headgear. Provide eye protection and hard hats as required by applicable safety regulations. Non-disposable type protective clothing and footwear shall be left in the Contaminated Equipment Room until the end of the asbestos abatement work, at which time such items shall be disposed of as asbestos waste, or shall be thoroughly cleaned of all asbestos or asbestos-containing material. Disposable type protective clothing, headgear, and footwear may be provided.

1.6.5 Provide authorized visitors with suitable protective clothing, headgear, eye protection and footwear, as described in Section 1.6.4, whenever they are required to enter the work area, to a maximum of [______] set(s) per day.

1.6.6 Provide and post, in the Equipment Room and the Clean Room, the decontamination and work procedures to be followed by workers, as described in Section 1.6.7 of these specifications.

1.6.7 Worker Protection Procedures

1.6.7.1 Each worker and authorized visitor shall, upon entering the job site: remove street clothes in the clean change room and put on a respirator with new filters, and clean protective clothing, before entering the equipment

NOTE TO USER

1.6.2 OSHA Regulations, 29 CFR 1910.1001 (d)(3), require respirators if airborne concentrations of asbestos fibers are higher than the OSHA standard of 2 f/cc 8 hour time weighted average or 10 f/cc peak exposures. The type of respirator required depends on concentrations:

1) half face respirator: if between 1 and 10x the standard;

2) powered air purifying respirator: if between 10 and 100x the standard; and

3) Type C respirator: if greater than 100x the standard.

The contractor is responsible for determination of the concentration of asbestos fibers in the air. This can be done by analysis of air samples from actual or similar jobs.

The OSHA regulations are not mandatory in Canada except where they have been officially adopted by an applicable jurisdiction. Some Canadian jurisdictions have adopted more stringent requirements.

1.6.4 In some instances job conditions may require that closer attention be given to the flame retardant qualities of the protective garments.

Guide Specifications For The Abatement of Asbestos Release from Spray- Or Trowel-Applied Materials In Buildings And Other Structures.

A GUIDANCE DOCUMENT ON ASBESTOS-CONTAINING BUILDING MATERIALS IN STRUCTURES.
DECEMBER, 1981

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PREAMBLE

This guide specification has been prepared to assist building owners, their representatives, and other officials responsible for the preparation of contract specifications for the abatement of exposure problems from spray- or trowel-applied asbestos-containing building materials in the United States and Canada. The guide specification is based on the Construction Specification Institute (CSI) format and is located in the left hand column, while notes to the user are in the right hand column. Users must study the suggested specifications and notes and either delete or add specifications where appropriate. **This guide specification must not be used as is but must be edited to fit the conditions at each particular job.** The specification includes actions required by regulation as well as actions offered as guidance for best current work practices. The guidance is based upon experience with abatement procedures and offers reasonable procedures for satisfaction of the regulatory requirements.

The final choice of language is up to the specifier. The authors of the guide specification are not responsible for the final wording of the project specification or the results of any work based on these guidelines. The reporting forms provided in Appendix B are examples only.

Specification writers must be thoroughly familiar with the guidance provided by the U.S. Environmental Protection Agency (EPA), and with Federal, State or Provincial, and municipal requirements, and must edit the guide specifications to suit applicable guidelines and regulations. [Writers must also have determined the appropriate abatement method **prior to editing these guide specifications.**] A complete assessment of conditions must be conducted in each building, including: an inspection for friable materials, sampling and analysis of suspect material by Polarized Light Microscopy (PLM) in the United States or by a method approved by Health and Welfare Canada and Provincial authority having jurisdiction in Canada, and an exposure assessment of the likelihood of release of asbestos fibers. Careful examination of the advantages and disadvantages of the various abatement methods should be completed before editing the specifications. For additional guidance in making these decisions, call the EPA at (800) 424-9065 or (202) 554-1404 and ask for the "Asbestos Information Packet."

It is recommended that building owners and their representatives require that contractors who submit bids for asbestos abatement work demonstrate that they have had experience in such work. They should require contractors to submit letters of reference from the owners of the buildings where this work was done, and air monitoring data taken during this work. As an alternative to, or in addition to, previous experience, building owners should require of contractors submitting bids that the contractors have successfully completed a training course in asbestos abatement work. If so, the contractors should be required to submit letters from the firm, agency, or association which conducted the training course and a syllabus of the session. Training sessions should include instruction in applicable regulations, work area isolation, worker protection, the selection, use, and maintenance of respirators, proper asbestos abatement techniques, and proper work area decontamination procedures.

Asbestos abatement work is done to reduce or eliminate free fiber movement. Abatement procedures must be done in accordance with regulations of all applicable agencies. **Incorrectly performed work may cause greater exposure problems than it eliminates.** In many projects other performance factors, such as fire resistance, flame spread, and acoustical or thermal requirements, must be met. Where the replacement/encapsulation/enclosure system is not equal to the original in required performance, or where the building code requirements have changed, the new system may have to meet new code requirements.

All specifications enclosed in brackets [ ] are offered as choices. Choose the specifications appropriate for the work and delete the other items.

1.3.17 Shower Room—a room between the clean room and the equipment room in the worker decontamination enclosure system, with hot and cold or warm running water and suitably arranged for complete showering during decontamination. The shower room comprises an airlock between contaminated and clean areas.

1.3.18 Equipment Room—a contaminated area or room which is part of the worker decontamination enclosure system, with provisions for storage of contaminated clothing and equipment.

1.3.19 Washroom—a room between the work area and the holding area in the equipment decontamination enclosure system. The washroom comprises an airlock.

1.3.20 Holding area—a chamber between the washroom and an uncontaminated area in the equipment decontamination enclosure system. The holding area comprises an airlock.

1.3.21 Fixed Object—a unit of equipment or furniture in the work area which cannot be removed from the work area.

1.3.22 Movable Object—a unit of equipment or furniture in the work area which can be removed from the work area.

1.3.23 HEPA filter—a high efficiency Particulate Absolute (HEPA) filter capable of trapping and retaining 99.97% of asbestos fibers greater than 0.3 microns in length.

1.3.24 Encapsulant (Sealant)—a liquid material which can be applied to asbestos-containing material and which controls the possible release of asbestos fibers from the material either by creating a membrane over the surface (bridging encapsulant) or by penetrating into the material and binding its components together (penetrating encapsulant).

1.3.25 Wet Cleaning—the process of eliminating asbestos contamination from building surfaces and objects by using cloths, mops, or other cleaning tools which have been dampened with water, and by afterwards disposing of these cleaning tools as asbestos-contaminated waste.

1.3.26 Negative Pressure—a local exhaust system capable of maintaining a minimum pressure differential of minus 0.02 inch of water column relative to adjacent unsealed areas.

SPECIFICATIONS

NOTE TO USER

1.3.7 Air Monitoring—the process of measuring the fiber content of a specific volume of air in a stated period of time.

1.3.8 HEPA Vacuum Equipment—high efficiency particulate air (absolute) filtered vacuuming equipment with a filter system capable of collecting and retaining asbestos fibers. Filters should be of 99.97% efficiency for retaining fibers of 0.3 microns or larger.

1.3.9 Surfactant—a chemical wetting agent added to water to improve penetration, thus reducing the quantity of water required for a given operation or area.

1.3.10 Amended water—a water to which a surfactant has been added (see 1.3.9).

1.3.11 Airlock—a system for permitting ingress or egress without permitting air movement between a contaminated area and an uncontaminated area, typically consisting of two curtained doorways at least 6 feet (2 meters) apart.

1.3.12 Curtained doorway—a device to allow ingress or egress from one room to another while permitting minimal air movement between the rooms, typically constructed by placing two overlapping sheets of plastic sheet over an existing or temporarily framed doorway, securing each along the top of the doorway, securing the vertical edge of one sheet along one vertical side of the doorway, and securing the vertical edge of the other sheet along the opposite vertical side of the doorway. Two curtained doorways spaced a minimum of 6 feet (2 meters) apart form an airlock.

1.3.13 Decontamination Enclosure System—a series of connected rooms, with curtained doorways between any two adjacent rooms, for the decontamination of workers or of materials and equipment. A decontamination enclosure system always contains at least one airlock.

1.3.14 Worker Decontamination Enclosure System—a decontamination enclosure system for workers, typically consisting of a clean room, a shower room, and an equipment room.

1.3.15 Equipment Decontamination Enclosure System—a decontamination enclosure system for materials and equipment, typically consisting of a designated area of the work area, a washroom, a holding area, and an uncontaminated area.

1.3.16 Clean Room—an uncontaminated area or room which is part of the worker decontamination enclosure system, with provisions for storage of workers' street clothes and protective equipment.

SPECIFICATIONS

NOTE TO USER

PART 1 — GENERAL

1.1. SCOPE. This specification covers the [removal] and [encapsulation] and [enclosure] of spray-applied and/or trowel-applied building materials that have previously been determined to contain asbestos.

1.1.1 The requirements of [______]shall be a part of this section.

1.1.2 Insert other requirements such as general conditions, supplementary general conditions, etc. Delete if not applicable.

1.2 DESCRIPTION OF WORK

1.2.1 Work specified in this section.

Furnish all labor, materials, services, insurance, equipment, in accordance with requirements of [EPA] and [OSHA] and [other regulatory agencies], to complete: [Removal] and [Encapsulation] and [Enclosure], as specified, of all [spray-] [trowel-] applied asbestos-containing material located as indicated on drawings.

1.2.1 Identify precisely, preferably by means of drawings, the extent of removal, encapsulation, enclosure, or any combination of these procedures, of spray or trowel applied asbestos-containing material, including work necessary to restore the project to specified condition (see 3.6)

1.2.2 Related work specified elsewhere.

1.2.2 Related work should be specified elsewhere, but should be referenced in this section. Other work includes replacement materials or systems for removal projects, and may also include work on electrical and mechanical systems, painting, air monitoring, panel ceilings, fire resistant coatings, and the like.

1.2.2.1 In some instances it may be acceptable, following gross cleaning, but prior to final cleanup, to apply replacement fire-resistive protection/insulation. In such instances all of the safety procedures outlined in this specification should be followed.

1.3 TERMINOLOGY (Definitions)

1.3.1 Building owner—the owner or his authorized representative.

1.3.2 Authorized Visitor—the building owner, or a representative of any regulatory or other agency having jurisdiction over the project.

1.3.3 Abatement—procedures to control fiber release from spray- or trowel-applied asbestos-containing building materials. Includes encapsulation, enclosure, removal.

1.3.4 Removal—All herein specified procedures necessary to strip all spray- or trowel-applied asbestos-containing materials from the designated areas and to dispose of these materials at an acceptable site.

1.3.5 Encapsulation—All herein specified procedures necessary to coat all spray- or trowel-applied asbestos-containing materials with an encapsulant to control the possible release of asbestos fibers into the ambient air.

1.3.6 Enclosure—All herein specified procedures necessary to complete enclosure of all spray- or trowel-applied asbestos-containing material behind airtight, impermeable, permanent barriers.

SPECIFICATIONS

NOTE TO USER

1.4 APPLICABLE REFERENCE DOCUMENTS
The current issue of each document shall govern. Where conflict among requirements or with these specifications exist, the more stringent requirements shall apply.

1.4.1 Regulations: Comply with applicable Federal, [State], [Provincial], municipal, and local regulations.

1.4.1 Specify model, State, Provincial or local building codes requirements affecting replacement materials or the use of encapsulants or enclosures. Delete where not applicable.

[Title 29, Code of Federal Regulations, Section 1910.1001. Occupational Safety and Health Administration (OSHA), U.S. Department of Labor.]

[Title 40, Code of Federal Regulations, Part 61, Subparts A and B, National Emission Standards for Hazardous Air Pollutants. U.S. Environmental Protection Agency (EPA).]

1.4.2 Codes and Standards

A. ASTM—American Society for Testing and Materials

B. ANSI—American National Standards Institute

1) ANSI Z 9.2 Fundamental Governing the Design and Operation of Local Exhaust Systems

C. CSA—Canadian Standards Association.

D. ULI—Underwriters Laboratories, Inc.

E. ULC—Underwriters Laboratories, Canada.

1.5 SUBMITTALS AND NOTICES

1.5.1 Prior to Commencement of Work

1.5.1 Notices and permits required by all federal, state, provincial and local agencies having jurisdiction must be specified.

A typical reporting form is provided in Appendix B.

1.5.1.1 Notify in writing of proposed asbestos work, with copy to building owner, the [EPA regional office] [OSHA Regional Office] [Regional or Zone Director of the Medical Services Branch, Health and Welfare Canada] [local air pollution agency] [local authority with responsibility for occupational health and safety] [Regional Office of Labour Canada] with jurisdiction over the [State] [Province] in which this project is located, not fewer than ten (10) days before work commences on this project.

1.5.1.2 Submit proof satisfactory to the building owner that all required permits, site location, and arrangements for transport and disposal of asbestos-containing or contaminated materials, supplies, and the like have been obtained.

1.5.1.2 Required for all abatement procedures.

SPECIFICATIONS

NOTE TO USER

1.5.1.3 Submit to the building owner a description of the plans for construction of decontamination enclosure systems and for isolation of the work areas in compliance with this specification and applicable regulations.

1.5.1.3 Use 1.5.1.3 if the contractor is responsible for the layout of enclosure. It is preferable, however, to define enclosures in the specifications.

1.5.1.4 Submit documentation to the building owner indicating that all employees have had instruction on the hazards of asbestos exposure, on use and fitting of respirators, on protective dress, on use of showers, on entry and exit from work areas, and on all aspects of work procedures and protective measures.

1.5.1.4 See Appendix B–for optional form to be signed by employees.

1.5.1.5 Post caution signs in and around the work area [to comply with OSHA regulation 29 CFR 1910.1001(g)(1)], [and] as required by federal, state, provincial regulation.

1.5.2 *Test Results*

1.5.2.1 Results of tests of asbestos-containing materials taken from surfaces within the scope of this project are [available for inspection at __________] [bound into this specification at the end of this section].

1.5.2.1 Test results are for general information only and are provided by the building owner or his authorized representative. Test results will not necessarily be representative of all asbestos-containing materials within the scope of this project.

1.5.2.2 Results of air monitoring tests taken by others prior to commencement of work are [available for inspection at __________] [bound into this specification at the end of this section].

1.5.2.2 Delete if not applicable.

A typical reporting form is provided in Appendix B.

1.5.2.3 Submit to the building owner, documentation, including test results, of encapsulating materials proposed for use.

1.5.2.3 Delete if encapsulation is not specified.

1.5.3 The contractor and the owner shall agree in writing on the condition of the building and fixtures, prior to commencement of the work.

1.5.4 Submit manufacturer's certification that vacuums, ventilation equipment, and other equipment required to contain airborne fibers conform to ANSI Z 9.2.

1.6 PERSONNEL PROTECTION

1.6.1 Prior to commencement of work, the workers shall be instructed, and shall be knowledgeable, in the areas described in Section 1.5.1.4.

room or the work area, except that workers intending to rewear contaminated protective clothing stored in the equipment room shall enter equipment room wearing only respirators.

1.6.7.2 Each worker and authorized visitor shall, each time he leaves the work area: remove gross contamination from clothing before leaving the work area; proceed to the equipment room and remove all clothing except respirators; still wearing the respirator proceed naked to the showers; clean the outside of the respirator with soap and water while showering; remove the respirator; thoroughly shampoo and wash themselves; remove filters and wet them and dispose of filters in the container provided for the purpose; and wash and rinse the inside of the respirator.

1.6.7.3 Following showering and drying off, each worker and authorized visitor shall proceed directly to the clean change room and dress in clean clothes at the end of each day's work, or before eating, smoking, or drinking. Before re-entering the work area from the clean change room, each worker and authorized visitor shall put on a clean respirator with filters and shall dress in clean protective clothing, except that workers intending to rewear contaminated protective clothing stored in the equipment room shall enter the equipment room wearing only respirators.

1.6.7.4 Contaminated work footwear shall be stored in the equipment room when not in use in the work area. Upon completion of asbestos abatement, dispose of footwear as contaminated waste or clean thoroughly inside and out using soap and water before removing from work area or from equipment and access area. Store contaminated protective clothing in the equipment room for reuse or place in receptacles for disposal with other asbestos contaminated materials.

1.6.7.5 Workers removing waste containers from the equipment decontamination enclosure shall enter the holding area from outside wearing a respirator and dressed in clean coveralls. No worker shall use this system as a means to leave or enter the washroom or the work area.

1.6.7.6 Workers shall not eat, drink, smoke, or chew gum or tobacco at the worksite except in the established clean room.

1.6.7.7 Workers shall be fully protected with respirators and protective clothing immediately prior to the first disturbance of asbestos-containing or contaminated materials and until final clean-up is completed.

1.7 EQUIPMENT REMOVAL PROCEDURES

1.7.1 Clean external surfaces of contaminated containers and equipment thoroughly by wet sponging or HEPA vacuum before moving such items into the equipment decontamination enclosure system washroom for final cleaning and removal to uncontaminated areas. Ensure that personnel do not leave work areas through the equipment decontamination enclosure system.

1.8 BUILDING PROTECTION

[Specify necessary security provisions]

1.8 Use 1.8 to cover items such as contractor's responsibilities for building security, fire safety, damages by the contractor, and the like. Delete if covered under general conditions.

PART 2 — MATERIALS AND EQUIPMENT

2.1 MATERIALS

2.1 It should not be inferred that all materials, tools, and equipment listed in Part 2 are required for all projects, or that all required materials, tools, and equipment necessary for every project are listed herein. Delete and add as applicable. Products may be specified by brand name in this section.

2.1.1 Deliver all materials in the original packages, containers, or bundles bearing the name of the manufacturer and the brand name.

2.1.1.2 Store all materials subject to damage off the ground, away from wet or damp surfaces, and under cover sufficient to prevent damage or contamination.

2.1.1.3 Damaged or deteriorating materials shall not be used and shall be removed from the premises. Material that becomes contaminated with asbestos shall be disposed of in accordance with the applicable regulations.

2.1.2 Plastic sheet, of 4 mil [0.1 mm] thickness unless otherwise specified, in sizes to minimize the frequency of joints.

2.1.2 Plastic sheet material provides a flexible vapor barrier and is used to isolate and seal off work areas and items within work areas; to protect surfaces in the work area other than those surfaces being altered; to construct decontamination and enclosure systems.

2.1.3 Tape—capable of sealing joints of adjacent sheets of plastic sheets and for attachment of plastic sheet to finished or unfinished surfaces of dissimilar materials and capable of adhering under dry and wet conditions, including use of amended water.

2.1.4 Surfactant [wetting agent]—shall consist of 50% polyoxyethylene ether and 50% of

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[polyoxyethylene] [polyglycol] ester, or equivalent, and shall be mixed with water to provide a concentration [of one ounce surfactant to 5 gallons of water] [of 1.25 kg/m³ of water].

2.1.5 Impermeable containers—suitable to receive and retain any asbestos-containing or contaminated materials until disposal at an approved site. [The containers shall be labeled in accordance with OSHA Regulation 29 CFR 1910.1001.] Containers must be both air- and water-tight.

2.1.5 It is recommended that two types of impermeable containers be used: 6 mil plastic bags size to fit within the drum listed hereafter and capable of being sealed; 55 gallon [200L] capacity metal or fiber drums with tightly fitting lids.

2.1.6 Warning labels and signs—as required [by OSHA regulation 29 CFR 1910.1001] [in official languages].

2.1.7 Encapsulants—[Bridging] [Penetrating] type, approved by the authority having jurisdiction and having the following characteristics:

2.1.7 Specify particular characteristics where more restrictive requirements apply, such as the effect of the encapsulant on the fire resistance, flame spread, or acoustical ratings.

At the time of publication of this guide specification ASTM Committee E6 is in the process of promulgating a series of test procedures (methods) for evaluating encapsulants.

Further information on encapsulants is available from EPA, 800-424-9065 or 202-554-1404. Avoid specifying an encapsulant that may affect the bond of the asbestos-containing material to its substrate or alter the fire rating of the material.

2.1.8 Spray or Trowel Applied Fire Resistant Materials—[ULI] [ULC] labeled and listed, asbestos-free [mineral fiber] [cementitious] material to provide the degree of fire protection required by the applicable building code.

2.1.8 Use 2.1.8 where repairs are required to existing sprayed or trowel-applied material prior to encapsulation or enclosure.

Where complete removal of existing spray- or trowel-applied material is specified in the United States, use CSI 07253 to specify the replacement materials in a separate section of this specification. In Canada, use GMS/NMS section 09841 to specify these replacement materials. The replacement material must provide equal performance to the original. If the applicable code requirements have changed, the replacement material must meet the new code requirements.

2.1.9 Spray- or trowel-applied thermal or acoustical insulation material used for patching or replacement shall provide performance characteristics equivalent to or better than the original material.

2.1.10 Enclosure materials—

2.1.10 Where fire, thermal or sound performance rated assemblies are required for enclosure projects, the applicable [ASTM] [ANSI] [CSA] [ULI] [ULC] [______] Material, Installation, Application Specifications or Recommended Practice should be specified.

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2.1.11 Other Materials—provide all other materials, such as lumber, nails and hardware, which may be required to construct and dismantle the decontamination area and the barriers that isolate the work area.

2.2 TOOLS AND EQUIPMENT

2.2.1 Provide suitable tools for asbestos [removal] [encapsulation] [enclosure].

A negative pressure may be established in the work area by means of mechanical equipment. This may assist in keeping airborne fibers confined to the work area. The mechanical equipment shall exhaust through a HEPA filter to the outside of the work area. The equipment shall be in operation for 24 hours per day until decontamination of the work area is completed.

2.2.1.1 Air movement equipment—High Efficiency Particulate Air Absolute Filtration Systems shall be equipped with filtration equipment in compliance with ANSI Z 9.2, Local Exhaust Ventilation. No air movement system or air equipment shall discharge asbestos fibers outside the work area.

2.2.1.1 Equipment capable of establishing a negative pressure and/or cyclic air changes in the work area can reduce fiber counts during abatement.

PART 3 — EXECUTION

3.1 PREPARATION

3.1.1 Work areas:

3.1.1.1 Shut down electric power. Provide temporary power and lighting and ensure safe installation of temporary power sources and equipment per applicable electrical code requirements and provide 24 V safety lighting and ground-fault interrupter circuits as power source for electrical equipment.

3.1.1.1 See also OSHA requirements for temporary electrical systems.

3.1.1.2 Shut down and isolate heating, cooling, ventilating air systems to prevent contamination and fiber dispersal to other areas of the structure. During the work, vents within the work area shall be sealed with tape and plastic sheeting.

3.1.1.3 Preclean movable objects [and carpeting] within the proposed work areas using HEPA filtered vacuum equipment and/or wet cleaning methods as appropriate, and remove such objects from work areas to a temporary location in [______].

3.1.1.3 Use 3.1.1.3 if Contractor is responsible for this work. Prior to commencing work, movable objects, and carpeting where feasible, should be removed from work areas. If any movable object is to remain in work areas, indicate, and specify protection under 3.1.1.4.

3.1.1.4 Preclean fixed objects within the proposed work areas, using HEPA filtered vacuum equipment and/or wet cleaning methods as appropriate, and enclose with minimum 4 mil plastic sheeting sealed with tape.

3.1.1.4 For sensitive equipment such as computers, additional protection may be required. The manufacturer of the equipment should be consulted to provide guidance for proper protection.

3.1.1.5 Clean the proposed work areas using HEPA filtered vacuum equipment or wet cleaning methods as appropriate. Methods that raise dust, such as dry sweeping or vacuuming with equipment not equipped with HEPA filters shall not be used.

3.1.1.6 Seal off all openings, including but not limited to corridors, doorways, skylights, ducts, grills, diffusers, and any other penetrations of the work areas, with plastic sheeting sealed with tape. Doorways and corridors which will not be used for passage during work must be sealed with barriers as described in 3.1.2.4.

3.1.1.6 Equipment capable of establishing a negative pressure and/or cyclic air changes in the work area can reduce fiber counts during abatement. If decontamination enclosure systems and barrier systems are not indicated on drawings, the Contractor should be required to provide a proposed layout under 1.5.1.3 of this section.

3.1.1.7 Cover floor and wall surfaces with plastic sheeting sealed with tape. [Use a minimum of two layers of 6 mil plastic on floors.] Cover floors first so that plastic extends at least 12 in. (300 mm.) up on walls, then cover walls with a minimum of 4 mil plastic sheeting to the floor level, thus overlapping the floor material by a minimum of 12 inches.

3.1.1.7 Where wall surfaces are smooth and non-porous the wall covering may not be necessary for protection. Asbestos fiber accumulation can be removed by HEPA vacuum equipment or wet cleaning during clean-up (section 3.5). However, the decorative surfaces or surface which are subject to damage from water and/or encapsulants will need protection. All openings must be individually sealed if the covering is not installed. Vinyl sheeting is available for improved traction.

3.1.1.8 Build airlocks (see 3.1.2.1.2) at entrances to and exits from the work areas.

3.1.1.9 Remove and clean ceiling mounted objects, such as lights and other items not previously sealed off, that interfere with asbestos abatement. Use localized water spraying or HEPA filtered vacuum equipment during fixture removal to reduce fiber dispersal.

3.1.1.10 Maintain emergency and fire exits from the work areas, or establish alternative exits satisfactory to the [______] [applicable fire officials].

3.1.1.11 After preparation of work areas and decontamination enclosure systems, remove ceiling [panels] [and] [tiles] within the work areas progressively and carefully, [clean using HEPA filtered vacuum equipment and damp sponge and wrap clean [panels] [tiles] in 0.10 mm. (4 mil.) minimum thickness plastic and store in building as directed by building owner] [and dispose of as contaminated waste]. Alternatively, surfaces of asbestos-contaminated items may be sprayed with an approved encapsulant prior to removal from the work area if permitted by local regulation. The encapsulated items may be disposed of in a regular landfill if permitted by local regulation.

3.1.1.11 Where it is necessary to remove suspended, furred, or other ceiling systems including panels, tile, lath and plaster and the like to make the work area accessible, specify where removal, cleaning/storing or disposal in this section to ensure that removal is under safe conditions. Delete sections 3.1.1.11-3.1.1.14 if not applicable.

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3.1.1.12 Where suspended ceiling suspension systems, such as T-grids, must be removed to expose and make work areas accessible [clean "T" grid using wet methods, disconnect grid from hangers, wrap cleaned grid members in 0.10 mm. (4 mil.) minimum thickness plastic and store as directed by building owner] [dispose of as contaminated waste].

3.1.1.13 Where suspended ceiling grid suspension systems removal is not required for work area accessibility, leave the grid system in place and, upon completion of the abatement work, clean the grid system as specified in 3.5.

3.1.1.14 After preparation of work areas and decontamination enclosure systems, remove plaster ceilings, including lath, furring channel system [grid], wire ties, clips, screws, and other accessory items and dispose of as contaminated waste. Spray ceiling debris and the immediate work area with amended water to reduce dust as the work progresses.

3.1.1.14 See note to 3.1.1.11. If the plaster ceiling material contains asbestos, removal should be performed in accordance with section 3.2.

3.1.2 Decontamination Enclosure Systems:

3.1.2.1.1 [Build suitable framing] [Use existing rooms connected with framed-in tunnels if necessary] and line with plastic, sealed with tape at all lap joints in the plastic for all enclosures and decontamination enclosure system rooms.

3.1.2.1.1 Either existing rooms outside of the work area or specially framed and sealed temporary areas may be used for the decontamination enclosure system. Convenience and proximity to the work area should be the determining factors. In some cases rooms may be connected by constructing temporary framed and sealed tunnels between existing rooms and the work area; these tunnels can also serve as airlocks.

3.1.2.1.2 In all cases access between contaminated and uncontaminated rooms or areas shall be through an airlock as described in Section 1.3. In all cases access between any two rooms within the decontamination enclosure systems shall be through a curtained doorway.

3.1.2.2 Worker Decontamination Enclosure System: Construct a worker decontamination enclosure system contiguous to the work area consisting of three totally enclosed chambers as follows:

3.1.2.2.1 An equipment room with two curtained doorways, one to the work area and one to the shower room.

3.1.2.2.1 See 29 CFR 1910.1001 (d)(4) for requirements.

3.1.2.2.2 A shower room with two curtained doorways, one to the equipment room and one to the clean room. The shower room shall contain at least one shower with hot and cold or warm water. Careful attention shall be paid to the shower enclosure to insure against leaking of any kind. Ensure a supply of soap at all times in the shower room. [Existing showers

may be used in conjunction with the decontamination system and procedures.]

3.1.2.2.3 A clean room with one curtained doorway into the shower and one entrance or exit to noncontaminated areas of the building. The clean room shall have sufficient space for storage of the workers' street clothes, towels, and other noncontaminated items.

3.1.2.3 Equipment Decontamination Enclosure System: Provide or construct an equipment decontamination enclosure system consisting of two totally enclosed chambers as follows:

3.1.2.3 The purpose of this area is to provide a means to decontaminate drums, scaffolding, material containers, vacuum and spray equipment, and other tools and equipment for which the worker decontamination system is not suitable. In some cases the worker decontamination enclosure can serve this purpose.

3.1.2.2.1 A washroom, constituting an airlock, with a curtained doorway to a designated area of the work area and a curtained doorway to the holding area.

3.1.2.3.2 A holding area, constituting an airlock, with a curtained doorway to an uncontaminated area.

3.1.2.4 Separation of Work Areas from Occupied Areas

3.1.2.4 Use this section where it is necessary to carry out asbestos abatement procedures in a building required to remain in use.

3.1.2.4.1 Separate parts of the building required to remain in use [as shown on drawings] from parts of the building that will undergo asbestos abatement by means of airtight barriers, constructed as follows:

3.1.2.4.1.1 Build suitable wood or metal framing and apply [⅜″] 9 mm. minimum thickness sheathing on [work side] [both sides].

3.1.2.4.1.1 It may be necessary, in certain occupancies, to construct these barriers with sheathing on both sides of the framing.

3.1.2.4.1.2 Cover sheathing with plastic sheet, sealed with tape as specified on work area side.

3.1.2.4.1.2 In certain occupancies, it may be necessary to cover both sides of sheathing on the work area side with plastic sheeting.

3.1.2.5 Maintenance of Enclosure Systems:

3.1.2.5.1 Ensure that barriers and plastic linings are effectively sealed and taped. Repair damaged barriers and remedy defects immediately upon discovery.

3.1.2.5.2 Visually inspect enclosures at the beginning of each work period.

3.1.2.5.3 Use smoke methods to test effectiveness of barriers when directed by building owner.

3.1.2.6 Asbestos abatement work shall not commence until:

3.1.2.6.1 Arrangements have been made for disposal of waste at an acceptable site.

3.1.2.6.2 Arrangements have been made for containing and disposal of waste water resulting from wet stripping.

3.1.2.6.2 For wet removal techniques. Delete if inapplicable.

3.1.2.6.3 Work areas and decontamination enclosure systems [and parts of the building required to remain in use] are effectively segregated.

3.1.2.6.4 Tools, equipment and material waste receptors are on hand.

3.1.2.6.5 Arrangements have been made for building security.

3.1.2.6.5 Delete if inapplicable.

3.1.2.6.6 All other preparatory steps have been taken and applicable notices posted and permits obtained.

3.2 ASBESTOS REMOVAL

3.2 Select the proper section for removal, encapsulation, enclosure or any combination of the three and delete non-applicable sections.

3.2.1 Prepare site (see section 3.1).

3.2.2 Spray asbestos material with amended water, using spray equipment capable of providing a "mist" application to reduce the release of fibers. Saturate the material sufficiently to wet it to the substrate without causing excess dripping or delamination of the material. Spray the asbestos material repeatedly during work process to maintain wet condition and to minimize asbestos fiber dispersion.

3.2.2 Small hand-held sprayers or a combination of water barrel, pump, hose and nozzle controlled sprayers may be used.

3.2.3 Remove the saturated asbestos material in small sections. As it is removed pack the material in sealable plastic bags of [6 mil] [0.15 mm.] minimum thickness and place in labeled containers for transport. Material shall not be allowed to dry out prior to insertion into the container.

3.2.4 Seal filled containers. [Place caution labels on containers in accordance with OSHA regulation 29 CFR 1910.1001 (g)(2).] Clean external surfaces of containers thoroughly by wet sponging in the designated area of the work area which is part of the equipment decontamination enclosure system. Move containers to washroom, wet clean each container thoroughly, and move to holding area pending removal to uncontaminated areas. Ensure that containers are removed from the holding area by workers who have entered from uncontaminated areas dressed in clean coveralls.

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Ensure that workers do not enter from uncontaminated areas into the washroom or the work area; ensure that contaminated workers do not exit the work area through the equipment decontamination enclosure system.	
3.2.5 After completion of stripping work, all surfaces from which asbestos has been removed shall be wire brushed and/or wet sponged or cleaned by an equivalent method to remove all visible material. During this work the surfaces being cleaned shall be kept wet.	*3.2.5 Where not possible to completely remove all traces of fibers by wire brush, wet sponge or other cleaning procedure, the surface may be encapsulated. However, it must be predetermined that the encapsulant to be used will be compatible with the new material to be applied.*
3.2.6 Where the building owner decides removal of asbestos-containing material is impossible due to obstructions such as structural members or major service elements, and provides a written direction, encapsulate the material as follows:	
3.2.6.1 [Apply bridging type encapsulant to provide [ ] mm. minimum dry film thickness over sprayed asbestos surfaces.] [Apply penetrating type encapsulant to penetrate existing sprayed asbestos materials to a depth of [ ] mm.]. [Apply penetrating type encapsulant to penetrate existing sprayed asbestos materials uniformly to substrate.] [When using a bridging type encapsulant, use a different color for each coat. Use [______] for final coat.] [During treatment with a penetrating encapsulant, remove selected random core samples of the asbestos-containing material in the presence of the owner to check the depth of penetration.] Apply encapsulant using airless spray equipment.	
3.2.7 Clean up shall be in accordance with 3.5.	
3.3 ASBESTOS ENCAPSULATION	*3.3 See Appendix A for information on an ASTM E06 task group activity dealing with the development of test methods for encapsulants.*
3.3.1 Prepare site (see Section 3.1.1).	
3.3.2 Repair damaged and missing areas of existing sprayed asbestos to obtain a suitable base for sealing and to restore continuity of existing material. Use the specified asbestos-free replacement material. Prepare surfaces and apply replacement material in accordance with manufacturer's recommendations.	
3.3.3 Remove loose or hanging asbestos material and pack in sealable plastic bags [6 mil] [0.15 mm] minimum thickness and place in labeled containers for transport.	

SPECIFICATIONS	NOTE TO USER
3.3.4 Seal filled containers. [Place caution labels on containers in accordance with OSHA regulation 29 CFR 1910.1001 (g)(2).] Clean external surfaces of containers thoroughly by wet sponging in the designated area of the work area which is part of the equipment decontamination enclosure system. Move containers to washroom, wet clean each container thoroughly, and move to holding area pending removal to uncontaminated areas. Ensure that containers are removed from the holding area by workers who have entered from uncontaminated areas dressed in clean coveralls. Ensure that workers do not enter from uncontaminated areas into the washroom or the work area; ensure that contaminated workers do not exit the work area through the equipment decontamination enclosure system.	
3.3.5 [Apply bridging type encapsulant to provide [ ] mm minimum dry film thickness over sprayed asbestos surfaces.] [Apply penetrating type encapsulant to penetrate existing sprayed asbestos materials uniformly to substrate, or to the depth of [ ] penetration as previously determined by field spray test. [When using a bridging type encapsulant, use a different color for each coat. Use [______] for final coat.] [During treatment with a penetrating encapsulant, remove selected random core samples of the asbestos-containing material in the presence of the owner to check the depth of penetration.] Apply encapsulant using airless spray equipment.	
3.3.6 Clean up shall be in accordance with 3.5.	
3.3.7 [Install warning signs (in both official languages) worded as follows: "STOP. Consult building management before working in this area." Install signs at locations indicated on drawings. A total of [______] signs will be required.]	*3.3.7 The decision whether to post signs and what language to use on the signs is up to the building owner. Delete if not applicable.*

3.4 ASBESTOS ENCLOSURE

3.4.1 Prepare site (See section 3.1).

3.4.2 Spray areas which will be disturbed while securing hangers and other fixing devices with water containing the specified wetting agent. Keep asbestos material damp to prevent release of airborne fibers.

3.4.3 Remove loose or hanging asbestos material while damp, [and place in sealable plastic bags of 6 mil [0.15 mm] minimum thickness] [and place in labeled containers for transport].

3.4.4 Seal filled containers. Place caution labels on containers in accordance with OSHA regulation 29 CFR 1910.1001 (g)(2). Clean external surfaces of containers thoroughly by wet sponging in the designated area of the work area which is part of the equipment decontamination enclosure system. Move containers to washroom, wet clean each container thoroughly, and move to holding area pending removal to uncontaminated areas. Ensure that containers are removed from the holding area by workers who have entered from uncontaminated areas dressed in clean coveralls. Ensure that workers do not enter from uncontaminated areas into the washroom or the work areas; ensure that contaminated workers do not exit the work area through the equipment decontamination enclosure system.

3.4.5 After installation of hangers and other fixing devices and before enclosing asbestos, repair damaged and missing areas of existing sprayed-on materials using the specified asbestos free replacement material. Prepare surfaces and apply in accordance with manufacturer's recommendations.

3.4.6 [Specify enclosure procedure]

3.4.6 There are so many ways to enclose asbestos surfaces that it is impossible to include a useful specification here. Specify methods to suit the particular situation.

3.4.7 Clean up shall be in accordance with 3.5.

3.4.8 [Install warning signs [in both official languages] worded as follows: "STOP. Consult building management before working in this area." Install signs at locations indicated on drawings. A total of [______] signs will be required.]

3.4.8 See note 3.3.7.

3.5 CLEAN UP

3.5.1 Remove visible accumulations of asbestos material and debris. Wet clean all surfaces within the work area.

3.5.2 Remove the plastic sheets from walls and floors only. The windows, doors, and HVAC vents shall remain sealed and any HEPA filtered negative air pressure systems, air filtration and decontamination enclosure systems shall remain in service.

3.5.3 Clean all surfaces in the work area and any other contaminated areas with water and/ or with HEPA filtered vacuum equipment. After cleaning the work area, wait 24 hours to allow for settlement of dust, and again wet clean or clean with HEPA filtered vacuum equipment all surfaces in the work area. After completion of the second cleaning operation, perform a complete visual inspection of the work area to ensure that the work area is free of visible asbestos debris.

3.5.4 Sealed drums and all equipment used in the work area shall be included in the clean-up and shall be removed from work areas, via the equipment decontamination enclosure system, at an appropriate time in the cleaning sequence.

3.5.5 If the building owner within [ ] hours finds visible accumulations of asbestos debris in the work area, the Contractor shall repeat the wet cleaning until the work area is in compliance, at the Contractor's expense.

3.5.6 When a final inspection determines that the area is free of accumulations of visible asbestos debris, the decontamination enclosure systems shall be removed, the area thoroughly wet cleaned, and materials from the equipment room and shower disposed of as contaminated waste. A final check shall be carried out to ensure that no dust or debris remains on surfaces as a result of dismantling operations.

3.5.6 A typical form for final inspection is provided in Appendix B.

3.5.7 As the work progresses, to prevent exceeding available storage capacity on site, remove sealed and labeled containers of contaminated waste and dispose of as contaminated waste (see section 3.7).

3.6 RE-ESTABLISHMENT OF OBJECTS AND SYSTEMS

3.6 Specify major restoration work such as respraying of fireproofing, and installation of new suspended ceilings or lighting, in the applicable sections of the specification.

3.6.1 When clean-up is complete:

3.6.1.1 Relocate objects moved to temporary locations in the course of the work to their former positions.

3.6.1.2 Re-secure mounted objects removed in the course of the work in their former positions.

3.6.2 Re-establish HVAC, mechanical and electrical systems in proper working order. Install new filters and dispose of used filters as contaminated waste.

3.6.2 Cleaning of ducts, if required, should be specified in this section.

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3.7 DISPOSAL

3.7 Disposal of asbestos-containing materials and asbestos-contaminated waste. As the work progresses, and to prevent exceeding available storage capacity on site, remove sealed and labeled containers of asbestos waste and dispose of such containers at an authorized disposal site in accordance with the requirements of disposal authority. Submit documentation regarding disposal to building owner.

NOTE TO USER

3.7 Sealed plastic bags may be dumped into the burial site unless the bags have been broken or damaged. Damaged bags shall remain in the drum and the entire contaminated drum shall be buried. Uncontaminated drums may be recycled. ***A typical form for the disposal of asbestos waste is provided in Appendix B.***

Appendix A — Guide Specifications - Asbestos

ASTM Committee E06.21.06E. on
Encapsulation of Building Materials

This task group is charged with the development of a Standard Specification For Encapsulating Agents For Friable Asbestos-Containing Building Materials.

The present scope of the "draft" standard describes the testing and performance of encapsulants designed to reduce or eliminate the release of asbestos fibers from the matrix of friable spray- or trowel-applied asbestos-containing building materials.

The "draft" standard consists of two separate test protocols with acceptance criteria:
1. a series of laboratory tests which show whether an encapsulant is capable of acceptable performance on a *specified asbestos-free matrix*, and;
2. a series of tests to be conducted in the field at each location where encapsulation is being considered, which show whether an encapsulant is acceptable on the specific asbestos-containing matrix.

Significance and Use:

This "draft" standard *does not* provide a means to determine whether encapsulation or any other control technique is suitable for any particular installation of friable asbestos-containing material, or guidance in making such a determination. The purpose of this "draft" standard is to provide guidance in the selection of an encapsulant once the decision to encapsulate has been made. It is assumed that users of this standard have already made a decision to encapsulate friable asbestos-containing material and that this decision is appropriate.

The test protocols in this standard *do not* cover the permeability to water vapor of encapsulants when applied to friable materials, or the mildew and fungus resistance of encapsulants, or the ability of penetrating encapsulants to control application amounts by tinting. These properties may be determined by other standard test methods. Since friable asbestos-containing materials originally were applied for a variety of purposes, these and other characteristics of encapsulant performance not included in this "draft" standard may be important to preserve originally intended qualities of the asbestos material.

The "proposed" test methods for laboratory testing are:
1. Cohesion and Adhesion
2. Penetration
3. Deflection
4. Surface Abrasion
5. Air Erosion
6. Fire Resistance
7. Surface Burning
8. Surface Impact

The "proposed" test methods for field testing are:
1. Adhesion and Cohesion
2. Penetration (for Penetrating Encapsulants only)
3. Fiber Release

It should not be assumed that the laboratory test results will replicate performance on friable asbestos-containing building materials. The laboratory tests are designed to evaluate the *relative behavior* of the encapsulants rather than to give a definitive indication of the performance on any particular friable asbestos-containing materials.

For all laboratory tests, the application of the encapsulant will be at the maximum or the minimum coverage rate noted in the individual test procedures. These maximum and minimum coverage rates are those specified by the manufacturers for field installation of his product. Coverage rates should be specified per unit surface for penetrating encapsulants.

Encapsulant coverage used in the field tests will be at the level required by the matrix system installation, but for the test to be valid, must be between the maximum and the minimum levels specified by the manufacturers.

It is the intent of the task group to complete its work in order to permit the proposed standard to be reviewed and balloted to consensus approval as expeditiously as possible, in order for it to be promulgated for use.

Users of this guide specification are referred to ASTM Headquarters for information on the status of the "draft" standard.

APPENDIX B

SAMPLE FORMS

1. **Air Test Sampling Data Sheet**
2. **Ten Day Notice Form** — To Regional EPA Office
3. **Asbestos Disposal Form**
4. **Final Inspection Form**
5. **Employee Release Form**

Air Test Samples
Sampling Data Sheet

Collected by ______________________

Analyzed by ______________________ Analytical Method ______________________

Job ______________________ Area ______________________

Sample No.	Sample Collection Information	Time. min.	Flow Rate lpm	Volume Sample l		Analysis Data			
						Fiber Count	Field Count	Fibers/ per cc	Remark

*** See Attached floor plan for sample locations.

I certify that the above samples were taken and the fiber counts performed in strict compliance with applicable standards and regulations.

____

Ten Day Notice Form

This form is to be filled in and filed with both state and regional EPA officials a minimum of twenty (20) days before start of the asbestos abatement contract.

Contractor ______________________________

Name ______________________________

Address ______________________________

City ______________ State ______________ Zip ______________

Phone (______) ______________________________

Building Owner or Operator ______________________________

Name ______________________________

Address ______________________________

City ______________ State ______________ Zip ______________

Phone (______) ______________________________

Building Information ______________________________

Age of Building ______________________________

Use of Building ______________________________

Address ______________________________

City ______________ State ______________ Zip ______________

Amount of Asbestos (Ft) ______________ Abatement Technique ______________

Amount of Asbestos (Ft) ______________ Abatement Technique ______________

Contract Dates Start ______________ Finish ______________

Disposal Site ______________________________

Site Name ______________ Operator-Owner Name ______________

Address ______________ Address ______________

City, State ______________ City, State ______________

Phone (______) ______________ Phone (______) ______________

Asbestos Disposal Form

Date: ______________________

Owner or Operator of Landfill ______________________

Name ______________________

Address ______________________

City ______________________ State ______________________ Zip ______________

Phone: (________) ______________________

Name of Landfill ______________________

Name ______________________

Address ______________________

City ______________________ State ______________________ Zip ______________

Phone (________) ______________________

Hauler ______________________

Approximate Volume of Asbestos Received ______________________

Type of Container Asbestos in ______________________

Asbestos Containers Labeled? ______ YES ______ NO

I certify that the above statements are true and that the landfill has been approved for the disposal of asbestos. The delivered material will be covered with 6 inches (15 cm.) of non-asbestos material within 24 hours.

____

Landfill Owner-Operator

Final Inspection

Form Time: ______________________

Date: ______________________

Name of Job ______________________

Name of Contractor ______________________

Location of Job ______________________

Address ______________________

City ______________ State ______________ Zip ______________

I have inspected the job-site and found it to be clean, orderly and dust-free. All work contracted for has apparently been performed in an acceptable manner in complete accordance with the specifications. There is no obvious damage to the structure.

Comments:

____

Contracting Agent

SEAL (If applicable)

Employee Release Form

Employee Name: ______________________________

Employee Address: ______________________________

Employee Telephone No.: ______________________________

Union Card Number: ______________________________

Classification of Worker: ______________________________

Have you had in the past, or present, any respiratory problems? Yes ______ No ______

Have you worked in the past with asbestos or fiberglass type materials? Yes ______ No ______

The project you will be working on involves the use of asbestos and the removal of the asbestos from the building. Asbestos is considered a health hazard.

The company is supplying all necessary safety clothing and working conditions required and necessary for your protection from asbestos hazard.

You shall be instructed at commencement of the job on the required use of safety equipment, clothing, working conditions and procedures. These must be rigidly adhered to. Smoking is not permitted in the work areas. Disregarding of safety instructions shall result in instant dismissal.

I acknowledge that safety instructions have been given to me by the company at my work commencement and I am thoroughly conversant with them and have answered the above questions truthfully.

Signed ______________________________
Employee

Date ______________________________

APPENDIX I

INSPECTING BUILDINGS FOR ASBESTOS

ONTARIO MINISTRY OF LABOUR

INSPECTING BUILDINGS FOR ASBESTOS

Prepared for Ministries of Education/
Colleges & Universities
by Ontario Ministry of Labour
Occupational Health and Safety Division

December, 1979

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PROCEDURES FOR THE INSPECTION OF ASBESTOS IN BUILDINGS

ASBESTOS AND HEALTH

Epidemiological studies of asbestos workers have shown that long-term exposure to asbestos increases the risks of developing lung cancer, mesothelioma (cancer of the lining of the lung and abdomen), and asbestosis (chronic lung disease). It is impossible to estimate confidently the exact degree of risk associated with low-level exposures. However, exposure to asbestos at any level is considered to present a health risk which increases with the duration and intensity of exposure.

The health effects of asbestos exposure do not become apparent immediately following exposure. The length of the latency period during which asbestos-related diseases develop is generally between 15 and 35 years from the time of the first exposure, depending upon the amount and duration of exposure.

The risk of developing asbestos-related diseases is increased considerably by cigarette smoking.

THE CONTROL OF ASBESTOS EXPOSURE IN BUILDINGS

The Use of Asbestos in Buildings

Asbestos is used in a variety of construction materials, principally applications where properties of heat resistance, fire-proofing and insulation are required. Products containing asbestos include reinforced asbestos cement, patching compounds, pipe insulation, fireproofing and decorative coatings.

Asbestos contained in building materials can become a health hazard when asbestos fibres are released into the air and inhaled. Many materials, such as vinyl floor tiles, will not release asbestos since the fibres are firmly encapsulated within the body of the material. However, friable (i.e. crumbly) materials containing asbestos will release fibres when damaged.

The asbestos materials of concern in buildings are the friable materials used for fireproofing, insulation or decoration. Friable materials are usually found on overhead surfaces, steel beams, ceilings and occasionally on walls and pipes. Many of these coatings are applied by spraying or trowelling.

Generally the sprayed materials are more friable. However, materials applied by trowelling also can release asbestos fibres if the coating is damaged.

It is important to note that asbestos is released from damaged materials such as surface coatings or insulation. This release can be stopped by careful removal of all loose material, followed by the application of a sealing solution to the damaged surface, or the enclosure of the damaged area.

The Control of Asbestos Exposure

In order to ensure that asbestos does not present a health hazard in buildings, the following precautions should be taken:

(a) Buildings should be inspected to locate situations where asbestos material is damaged and exposed.

(b) Samples of the material should be carefully collected.

(c) The samples should be analyzed for asbestos.

(d) If the material contains asbestos, an exposure assessment should be carried out to determine whether an exposure problem exists.

(e) If an exposure problem is discovered, corrective action should be taken. Appropriate courses of action include removal, encapsulation, or enclosure of the asbestos-containing material.

(f) A list of locations where friable asbestos material is used should be kept up-to-date.

Each of these precautionary measures is discussed in more detail in the following sections.

PROCEDURES FOR INSPECTION OF ASBESTOS

A survey of buildings should be carried out initially by maintenance staff, in order to locate areas where asbestos is contained in building materials. These materials include spray coats on ceilings or steel beams for fireproofing, decorative coatings, and pipe insulation. Situations of particular importance are those where coatings are damaged.

A check of building and maintenance records should supplement visual inspections. However, record checks should not replace visual inspection in identifying asbestos material.

When it is suspected that asbestos is contained in building materials in any area, a location record should be started for future reference.

When damaged surfaces containing asbestos are located, a plastic drop sheet should be placed under the damaged area to catch released material. The surrounding area should be carefully vacuumed to capture fallen material. Warning signs should be posted and the area isolated.

Engineering staff should then be advised of the situation. Collection of samples for analysis should be taken immediately according to the instructions detailed below. Subsequent removal or repair of the coatings should be carried out by contractors and supervised by engineering staff.

COLLECTION OF SAMPLES FOR ANALYSIS

Sample Collection

A small sample (not more than a teaspoon in quantity) of suspected asbestos-containing material is required for analysis. The following precautions should be taken during sample collections:

(a) The material from which the sample is drawn should not be otherwise disturbed or damaged.

(b) The area around the damaged material should be sprayed with a light mist of water to prevent further damage and fibre release during collection.

(c) If pieces of the damaged material break off during sample collection, all floors and surfaces in the area should be vacuumed or cleaned with a wet mop.

(d) Only those persons involved in sample collection and clean-up should be present in the area, and suitable respirators should be worn. Shoes and clothing should be decontaminated by vacuuming. For more information on the respirators available, call the Occupational Hygiene Service, of the Occupational Health Branch at (416) 965-3150.

During the collection of samples, a plastic drop sheet should be placed below the damaged surface to catch the friable material released. If scraping is necessary, it should be done very gently with a thin metal spatula commonly used in the chemistry laboratory.

The sample of the suspect material should be placed in an airtight sample bag available from the Ministry of Labour, sealed and sent in the accompanying envelope to the following address:

Occupational Health Laboratory
Ministry of Labour
360 Christie Street
Toronto, Ontario M3G 3C2

The envelope should be clearly marked in the lower left-hand corner;

ASBESTOS INSPECTION PROGRAM

The form enclosed with the sampling pouch must be filled out. This form indicates where the final results of the sample analysis are to be sent. A sample reporting form is shown in APPENDIX I.

Exposure Assessment

When sample results indicate that asbestos is present, it will be necessary to assess the potential for release into the environment. This should be done by contractors or maintenance staff, using suitable respiratory equipment.

CORRECTIVE ACTION THAT SHOULD BE TAKEN TO CONTROL THE RELEASE OF ASBESTOS

If friable asbestos material is identified and exposure is occurring or is likely to occur, corrective action should be considered.

In deciding which course of corrective action provides the most efficient long-term solution, consideration should be given to the present condition of the materials containing asbestos, the location of this material, its function, and the cost of the proposed method of controlling asbestos exposure.

There are four basic approaches to controlling exposure:

(a) Removal: Asbestos material is removed and disposed of by burial.

(b) Encapsulation: Asbestos material is coated with a bonding agent called a sealant.

(c) Enclosure: Asbestos material is separated from the building environment by barriers such as suspended ceilings.

(d) Deferred action: No action is taken. The area is inspected periodically for changes in exposure potential.

Removal, encapsulation, and enclosure are corrective methods and can be used separately or in combination. Removal completely eliminates the source of exposure to asbestos and, therefore, offers a permanent solution. Both enclosure and encapsulation are containment methods which do not remove the source of asbestos exposure.

Since the asbestos material remains within the building following enclosure or encapsulation, these approaches should be considered only as temporary control measures. The expected length of time before a building is to be demolished or major structural changes are to be made will be a factor in deciding whether to use either

of these methods. If a building is later renovated or demolished, encapsulated and enclosed asbestos material should be removed and disposed of by methods acceptable to the Ministry of Labour and the Ministry of Environment.

The following explains each of the above corrective measures in more detail:

(a) Removal

For removal, all the asbestos material is taken off the underlying surface, collected and placed in containers for burial in an approved waste disposal site. This process may require interruption of building activities.

Fireproofing material which has been removed should be replaced immediately to maintain compliance with fire and building codes. If the asbestos material fulfilled either an insulating or acoustical function, a replacement material should have similar characteristics.

(b) Encapsulation

For encapsulation, the asbestos material is coated with a bonding agent called a sealant. Sealants penetrate and harden the asbestos material (penetrants) or cover the surface of the material with a protective coating (bridging sealants). The sealant prevents fibre release from the asbestos material.

Sealants are applied over the surface of the material using airless spray equipment at a low pressure setting. Airless equipment reduces the pressure of the sealant spray and the impact upon the friable asbestos material surface, thus reducing fibre release during application.

Encapsulation should be limited to areas where the asbestos containing material will not be subject to further damage by contact. This factor may preclude the use of encapsulation as a corrective measure in many areas since activity in the buildings may result in contact with treated surfaces and subsequent damage. Encapsulation should also be limited to asbestos material which is capable of supporting the additional weight of the sealant.

Encapsulated material should be routinely inspected for deterioration or damage.

Sealants found satisfactory for asbestos encapsulation are listed in APPENDIX II.

(c) Enclosure

For enclosure, a barrier such as a suspended ceiling is constructed between the asbestos material and the building environment. Since the asbestos material has not been removed, fibres will continue to be released and will accumulate behind this barrier. When the enclosure is damaged or entered for maintenance, this accumulation may be released into the building environment.

(d) Deferred Action

In the event that action is deferred, a continuing inspection program should be implemented. The asbestos material should be routinely checked for deterioration or damage. If the condition of the material changes so that fibres are being released and contaminating the building environment, corrective action should be considered.

ACTION THAT SHOULD BE TAKEN TO PREVENT FUTURE EXPOSURE

Encapsulation, enclosure, and deferred action allow the asbestos material to remain within the building. It is important to recognize, therefore, that the risk of hazardous asbestos exposure may be increased by changing conditions in the building. For example, asbestos material can be damaged by maintenance, repair, or renovation activities, causing further fibre release.

Consequently, a management system should be implemented to ensure that asbestos is not released into the building environment due to maintenance, renovation, or repair work performed by either building personnel or contractors.

All individuals involved in such activity should be informed that asbestos material is present and trained in work procedures to prevent damage to material containing asbestos.

Generally, it is not necessary to close a building in order to take corrective action. However, areas or rooms where there is a severe exposure hazard may have to be closed off until corrective action is taken. Usually this situation arises when there is a potential for high contamination levels of asbestos caused by continuing damage of highly friable material.

ASBESTOS INSPECTION PROGRAM

NAME OF PERSON TO RECEIVE
THESE RESULTS:

NAME OF BUILDING

ADDRESS:

PERSON IN CHARGE OF BUILDING:

TELEPHONE NUMBER:

NO. OF SAMPLES SUBMITTED:

SAMPLING LOCATIONS	SAMPLE #	DATE SAMPLED

RESULTS

SAMPLE #	PRESENCE OF ASBESTOS

SEALANT MATERIALS TESTED BY BATTELLE LABORATORIES FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY AND FOUND SATISFACTORY FOR ASBESTOS ENCAPSULATION

Material	From
Decadex Firecheck	Pentagon Plastics 7659C Fullerton Rd. Springfield, Va. 22153 Tel: 703-569-5277
554-21-1	H.B. Fuller Company Foster Division Box 625 Springhouse, Penn. 19477 Tel: 215-628-2600
X-64-2 Also known as OX line ABC sealer	Lehman Bros. Corp. 22 Halladay Street Jersey City, N.J. 07304 Tel: 201-434-1882
Cafco Bond Seal	United States Mineral Products Co. Flanders Road Stanhope, N.J. 07874 Tel: 201-347-1200

Material	From
K-13 Sprayed Cellulose	National Cellulose Corporation 12315 Roben Blvd. Houston, Texas 77045 Tel:713-433-6701
Pleco-glo	Makus Development Corporation P.O. Box 31 Mercer Island, Belleview Washington. Tel:206-641-7373

APPENDIX J

MINISTRY OF GOVERNMENT SERVICES GUIDELINES
REGARDING ASBESTOS (INSPECTION, MAINTENANCE,
REPAIR, CONSTRUCTION AND DEMOLITION)

GUIDELINES REGARDING ASBESTOS RELATING TO INSPECTION, MAINTENANCE, REPAIR, CONSTRUCTION AND DEMOLITION WORK BY MINISTRY OF GOVERNMENT SERVICES PERSONNEL

MINISTRY OF GOVERNMENT SERVICES

OCCUPATIONAL EXPOSURE

Exposure to asbestos fibres in air can occur in a variety of uses and processes. The fibrous material may be sprayed as insulation, as a fire retardant, or for acoustic effect. Asbestos is combined in cement asbestos board, shingles, brake linings, paints, floor tiling, water and sewer pipes, and is used in the production of moulded plastic products, in sheet form as lagging for insulation and in flame retardant cloth.

GUIDELINES

The following guidelines have been derived from the Ontario Ministry of Labour guidelines regarding occupational exposure to asbestos (Occupational Health Branch Data Sheet No.18) with clarification or adaptations of the guidelines for Ministry of Government Services operations.

These guidelines are designed to provide for the protection of workers and others from potentially hazardous exposure to asbestos during inspection, maintenance, repair, construction, and demolition activities undertaken by the Ministry of Government Services. It is the responsibility of all Ministry of Government Services personnel engaged in such activities to adhere to and carry out the provisions of these guidelines in areas where a potentially hazardous asbestos exposure is known, suspected or may result from the activity.

In all cases involving worker exposure to asbestos, Ministry of Labour guidelines, standards or directions regarding asbestos exposure shall govern.

(1) Personal Hygiene

(a) Good personal hygiene is to be maintained. This includes washing before eating, drinking, smoking or use of toilet facilities following an exposure to asbestos contamination. Care should be taken to wash those areas of the body where no protective covering was used (face, hands, etc.)

(b) Change areas/rooms are to be provided for so that workers may remove protective outer clothing or change clothes which may have been contaminated by asbestos fibres. Occupied public areas, locker/change rooms used for general purposes, and restroom facilities should not be used for change areas/rooms as described in this section.

Personal Hygiene (Continued)

(c) Where feasible, a vacuum cleaner should be used to vacuum contaminated clothing prior to removal of such clothing from the person. The vacuum operation should be performed,where possible, prior to leaving the contaminated area. If a vacuum cleaner is not available, any visible asbestos fibres should be brushed from the clothes prior to leaving the contaminated area.

(d) Strong, disposable vacuum bags shall be used in the vacuum unit. Used vacuum bags should be disposed of in a safe manner so that hazardous concentrations of asbestos will not be released.

(e) Contaminated clothing shall be placed in a covered impermeable container.

(f) Contaminated clothing should not be worn by the worker outside of the area of contamination except to the location of any change area. Contaminated clothing should not be taken home by the worker.

(g) Laundry

(i) Laundering of asbestos-contaminated clothing is to be done so as to prevent the release of hazardous levels of airborne asbestos fibres.

(ii) An employer who gives asbestos-contaminated clothing to another person or company for laundering is to inform such person or company of the requirement in subsection (i) above.

(iii) Contaminated clothing is to be transported is sealed impermeable bags, or other closed impermeable container and a caution label affixed (see Section 3(i)).

(h) The worker shall clean by vacuuming and/or wet wiping any item of contaminated equipment or clothing (shoes, hat, etc.) which will not be laundered prior to re-use.

(i) Areas used for changing contaminated clothing shall be vacuumed and/or washed thoroughly following use.

(2) Food, Beverages and Tobacco

Food, beverages and tobacco are not to be kept nor consumed in the contaminated work area nor in the change area for contaminated clothing.

(3) Caution Labels

(i) Labelling - Caution labels are to be affixed to all raw materials, mixtures, scrap, waste, debris and other products containing asbestos fibres, or to their containers, except that no label is required where asbestos fibres have been modified by a bonding agent, coating, binder or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing or transportation, no hazardous concentrations of asbestos fibres will be released.

(ii) Labels - All labels are to be in accordance with the Guidelines for the Labelling of Toxic Chemicals for Use in Ontario Industry.

(4) Personal Protective Equipment/Clothing

(a) Persons who work in an area of known or suspected hazardous asbestos exposure shall wear a reusable or replaceable filter type air purifying dust respirator or single-use dust respirator suitable for filtration of asbestos fibres from the breathing air.

Suitable dust respirators include:

Willson No.1210 Respirator with R10 replaceable filter

Willson No.1211 Respirator with R11 repleacable filter

3M Toxic Dust Disposable Respirator No.9900

3M Disposable Dust Respirator No.8710

3M Dust/Mist Respirator No.9910

Safety Supply No.1400 Disposable Respirator

Safety Supply No.560 Respirator with R60 replaceable filter

Levitt MW 7170 Re-usable Dust Mask

or equivalent dust respirators suitable for protection from airborne asbestos fibres.

(b) Persons who work in an area of known or suspected hazardous asbestos exposure should be provided with reusable or disposable protective coveralls or similar protective clothing for use when in a contaminated area. The coveralls should completely cover the regular clothes and should be closed at the neck when worn in a contaminated area. Coveralls should be laundered or disposed of prior to re-use (see Section 1-g).

Personal Protective Equipment/Clothing (Cont'd)

(c) A head covering such as a safety hard hat, safety bump cap, or other protective cap/hat should be worn while in a contaminated area.

(d) Protective gloves should be worn, when feasible, during direct handling of asbestos material.

(e) Where there is a reasonable possibility that airborne concentrations of asbestos in a location are or may become excessive, contact Safety Section, Ministry of Government Services, prior to workers entering the area or commencing work respectively.

(5) Housekeeping

Housekeeping includes prompt vacuum cleaning or wet sweeping of all scraps and spills, careful storage and disposal of asbestos containing materials in plastic bags or other suitable containers, and frequent and regular cleaning of machines, floors, wall and other surfaces (by vacuum cleaning or wet wiping) where asbestos dust settles. Dry sweeping, dusting or use of compressed air are not acceptable.

(6) Ventilation

The use of adequate local exhaust installed for the project, where feasible, is the most important method of dust control. This method captures the dust at the source and conveys it to a central collecting system.

(7) Disposal

Disposal of asbestos or asbestos-containing material shall be done in a manner consistent with applicable Provincial and Municipal regulations.

(8) Work Practices

Work practices are to be followed, as completely as possible, that prevent the dissemination of dust.

Examples are:-

(a) When dumping bags of asbestos:

(i) Local exhaust is to be used.

(ii) Excessive shaking of bags is to be avoided.

(iii) Bags are to be disposed of carefully using local exhaust, covered containers, plastic bags that can be sealed, etc.

(b) When sawing, drilling, grinding, machining asbestos-containing materials, etc.

(i) Local exhaust is to be used.

(ii) Products are to be vacuum cleaned, washed or otherwise cleaned before further operations, storage or shipping.

Compressed air is not to be used for cleaning.

(c) Where work in ceiling areas may create a possible hazardous asbestos exposure in an occupied area below the ceiling:

(i) The area below the ceiling should be protected by the use of drop-sheets and protective enclosures to prevent the spread of the asbestos fibres.

(ii) Personnel not engaged in the inspection/maintenance/repair/construction/demolition work, including those normally occupying the local area, should not be working within or passing through the area bounded by the protective enclosures.

(iii) Care should be taken to ensure that loose airborne asbestos fibres created by the work activity will not enter other work areas through the ventilation system(s).

(iv) The drop sheets and enclosures should be vacuumed and/or wet cleaned prior to removal.

(v) Following removal of the drop sheets and enclosures, the exposed surfaces or the area should be vacuumed and/or wet cleaned thoroughly.

(d) The same provisions as outlined in subsections a, b and c above apply to any inspection, maintenance, repair, construction or demolition work where airborne asbestos fibres as a result of the activity may create a possible hazardous asbestos exposure to persons not engaged in the activity. Arrangements will be made by the Ministry of Government Services to temporarily relocate such personnel, if required, to an adjacent or other area not affected by the work activity.

Other precautions may also be necessary consistent with the nature of the workplace and the work being performed.

Questions regarding these specific guidelines or any other aspect concerning a possible asbestos hazard in a Ministry of Government Services workplace should be referred to Safety Section, Ministry of Government Services Property Management Branch: 965-6517. The Ontario Ministry of Labour will serve as the authority having jurisdiction for any problem involving an occupational exposure to asbestos.

Property Management Branch
Ministry of Government Services

APPENDIX K

DETAILED RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

INSPECTION ABOVE SUSPENDED CEILING

Job Number 82304

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type *
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	
Filter 41405-NUC 03 Area with Amosite Insulation and Ceiling Tiles Containing Chrysotile Inspector working above ceiling	0.083	0 - 0.19	0.7	0.0138	<0.02	-	-	0.0138	C
	0.069	0 - 0.16	14	0.0138	<0.02	-	-	0.0138	A
Filter 41405-NUC 04 Area with Amosite Insulation and Ceiling Tiles Containing Chrysotile Observer in room as inspector worked	0.16	0.018 - 0.29	0.7	0.0155	<0.02	-	-	0.0155	C
	0.23	0.085 - 0.38	460	0.0155	0.016	0 - 0.048	420	0.0155	A
Filter 41405-NUC 05 Area with Amosite Insulation Background Sample	0.037	0 - 0.075	0.2	0.0073	<0.008	-	-	0.0073	C
	0.029	0 - 0.065	3.1	0.0073	<0.008	-	-	0.0073	A
Filter 41405-NUC 06 Area with Chrysotile Insulation Background Sample	0.046	0.006 - 0.086	0.1	0.0077	<0.008	-	-	0.0077	C
	0.046	0.012 - 0.080	1.5	0.0077	<0.008	-	-	0.0077	A

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (SAED)
*C = Chrysotile (morphology)

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

MAINTENANCE ABOVE SUSPENDED CEILING

Job Number 82313

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type *
	Fibre Concentration: Mean (Fibres/mL)	Fibre Concentration: 95% Confidence Interval (Fibres/mL)	Estimated Mass Concentration (Nanograms/m^3)	Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	Fibre Concentration: Mean (Fibres/mL)	Fibre Concentration: 95% Confidence Interval (Fibres/mL)	Estimated Mass Concentration (Nanograms/m^3)	Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	
Filter TEM 1 Distant from work site	0.073	0 - 0.16	0.6	0.0056	<0.006	-	-	0.0056	C
	0.045	0.009 - 0.080	7.4	0.0056	<0.006	-	-	0.0056	A
Filter TEM 3 Worker adjacent to vacuuming (Assumed air volume of 1 m^3)	0.20	0.082 - 0.31	4.3	0.0062	<0.007	-	-	0.0062	C
	0.068	0.025 - 0.11	6.1	0.0062	<0.007	-	-	0.0062	A
Filter TEM 5 Worker performing vacuuming above ceiling	370	300 - 430	6400	1.03	12	9.3 - 14	1100	0.154	C
	<1.1	-	-	1.03	<0.2	-	-	0.154	A
Filter TEM 8 Close to work site	0.14	0.050 - 0.24	1.4	0.0130	<0.02	-	-	0.0130	C
	0.039	0 - 0.084	1.2	0.0130	<0.02	-	-	0.0130	A

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (SAED)
*C = Chrysotile (morphology)

PROJECT NUMBER 1 - BEFORE START OF PROJECT

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

Job Number /9351

Sample	TOTAL FIBRES				FIBRES > 5.0 MICRONS LONG				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	*
	Mean (Fibres/ml)	95% Confidence Interval (Fibres/ml)	(Nanograms/m^3)	(Fibres/ml)	Mean (Fibres/ml)	95% Confidence Interval (Fibres/ml)	(Nanograms/m^3)	(Fibres/ml)	
Room 127	0.005	0 - 0.017	2.3	0.005	<0.005	-	-	0.005	A
	0.035	0.006 - 0.064	0.045	0.005	<0.005	-	-	0.005	C
Room 128	<0.0051	-	-	0.0051	<0.0051	-	-	0.0051	A
	0.01	0 - 0.026	0.092	0.0051	<0.0051	-	-	0.0051	C
Room 157	<0.0054	-	-	0.0054	<0.0054	-	-	0.0054	A
	0.011	0 - 0.028	0.044	0.0054	<0.0054	-	-	0.0054	C
Corridor E	<0.0052	-	-	0.0052	<0.0052	-	-	0.0052	A
	0.047	0.0017 - 0.093	0.33	0.0052	<0.0052	-	-	0.0052	C

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (positive SAED)
*C = Chrysotile (morphology)

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

PROJECT NUMBER 1 - AFTER CLEAN-UP

Job Number 82305

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	*
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	
Filter NUC 01 Room 127	0.056	0.005 - 0.11	0.2	0.0037	<0.004	-	-	0.0037	C
	<0.004	-	-	0.0037	<0.004	-	-	0.0037	A
Filter NUC 02 Room 128	0.024	0 - 0.051	0.05	0.0034	<0.004	-	-	0.0034	C
	0.038	0.013 - 0.062	2.0	0.0034	<0.004	-	-	0.0034	A
Filter NUC 03 Corridor E	0.022	0 - 0.044	0.7	0.0043	<0.005	-	-	0.0043	C
	0.030	0.010 - 0.050	1.3	0.0043	<0.005	-	-	0.0043	A
Filter NUC 05 Ambient Air Near Mechanical Room	0.021	0 - 0.044	0.1	0.0035	<0.004	-	-	0.0035	C
	0.010	0 - 0.026	0.3	0.0035	<0.004	-	-	0.0035	A

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (SAED)
*C = Chrysotile (morphology)

PROJECT NUMBER 2

BEFORE START OF PROJECT

Job Number 81166

Sample	FIBRES OF ALL LENGTHS: Fibre Concentration: Mean (Fibres/mL)	FIBRES OF ALL LENGTHS: Fibre Concentration: 95% Confidence Interval (Fibres/mL)	FIBRES OF ALL LENGTHS: Estimated Mass Concentration (Nanograms/m³)	FIBRES OF ALL LENGTHS: Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Fibre Concentration: Mean (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Fibre Concentration: 95% Confidence Interval (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Estimated Mass Concentration (Nanograms/m³)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	Fibre Type *
JULY 7, 1981									
Filter 2649-1 Fan Room	0.011	0 - 0.023	0.03	0.0016	<0.002	-	-	0.0016	C
	<0.002	-	-	0.0016	<0.002	-	-	0.0016	AD
	0.013	0.001 - 0.024	4.5	0.0016	0.003	0 - 0.008	1.4	0.0016	SA
Filter 2649-2 Room 119	0.011	0.002 - 0.020	0.05	0.0016	<0.002	-	-	0.0016	C
	<0.002	-	-	0.0016	<0.002	-	-	0.0016	AD
	0.006	0 - 0.012	2.0	0.0016	0.002	0 - 0.005	1.6	0.0016	SA
Filter 2649-3 Room 218	0.011	0.001 - 0.021	0.04	0.0016	<0.002	-	-	0.0016	C
	0.003	0 - 0.008	0.5	0.0016	0.002	0 - 0.005	0.4	0.0016	AD
	0.003	0 - 0.008	2.6	0.0016	0.002	0 - 0.005	1.4	0.0016	SA
Filter 2649-4 Room 319	0.003	0 - 0.007	0.01	0.0015	<0.002	-	-	0.0015	C
	<0.002	-	-	0.0015	<0.002	-	-	0.0015	AD
	0.002	0 - 0.005	1.0	0.0015	0.002	0 - 0.005	1.0	0.0015	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD = Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA = Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 2

AFTER CLEAN-UP

Job Number 81202

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	*
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	
AUGUST 14, 1981									
Filter 2649-17 Basement	0.011	0.002 - 0.020	0.2	0.0022	<0.003	-	-	0.0022	C
	0.002	0 - 0.007	120	0.0022	0.002	0 - 0.007	120	0.0022	AD
	0.015	0.005 - 0.025	34	0.0022	<0.003	-	-	0.0022	SA
Filter 2649-19 Room 220	0.044	0.027 - 0.062	6.2	0.0021	0.004	0 - 0.010	1.1	0.0021	C
	<0.003	-	-	0.0021	<0.003	-	-	0.0021	AD
	0.015	0.005 - 0.025	58	0.0021	0.004	0 - 0.010	52	0.0021	SA
Filter 2649-21 Room 319	0.047	0.027 - 0.067	26	0.0021	0.004	0 - 0.010	18	0.0021	C
	0.002	0 - 0.007	1.3	0.0021	<0.003	-	-	0.0021	AD
	0.026	0.007 - 0.044	150	0.0021	0.009	0 - 0.017	130	0.0021	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD = Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA = Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 3

BEFORE START OF PROJECT

Job Number 81158

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	*
JUNE 26, 1981									
Filter 2647-1 Bottom Floor Northeast corner	0.008	0 - 0.017	0.02	0.0017	<0.002	-	-	0.0017	C
	0.003	0 - 0.008	2.2	0.0017	<0.002	-	-	0.0017	AD
	0.005	0 - 0.011	0.3	0.0017	<0.002	-	-	0.0017	SA
Filter 2647-2 Room 106	0.002	0 - 0.005	0.005	0.0017	<0.002	-	-	0.0017	C
	0.002	0 - 0.005	0.4	0.0017	<0.002	-	-	0.0017	AD
	0.007	0 - 0.013	1.0	0.0017	0.002	0 - 0.005	0.1	0.0017	SA
Filter 2647-3 2nd Floor	0.004	0 - 0.009	0.005	0.0019	<0.002	-	-	0.0019	C
	0.002	0 - 0.006	0.4	0.0019	<0.002	-	-	0.0019	AD
	0.011	0.003 - 0.019	0.9	0.0019	0.002	0 - 0.006	0.1	0.0019	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD= Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA= Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 3

BEFORE START OF PROJECT

Job Number 81158

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m³)	(Fibres/mL)	*
JUNE 26, 1981									
Filter 2647-1	0.008	0 - 0.017	0.02	0.0017	<0.002	-	-	0.0017	C
Bottom Floor	0.003	0 - 0.008	2.2	0.0017	<0.002	-	-	0.0017	AD
Northeast corner	0.005	0 - 0.011	0.3	0.0017	<0.002	-	-	0.0017	SA
Filter 2647-2	0.002	0 - 0.005	0.005	0.0017	<0.002	-	-	0.0017	C
Room 106	0.002	0 - 0.005	0.4	0.0017	<0.002	-	-	0.0017	AD
	0.007	0 - 0.013	1.0	0.0017	0.002	0 - 0.005	0.1	0.0017	SA
Filter 2647-3	0.004	0 - 0.009	0.005	0.0019	<0.002	-	-	0.0019	C
2nd Floor	0.002	0 - 0.006	0.4	0.0019	<0.002	-	-	0.0019	AD
	0.011	0.003 - 0.019	0.9	0.0019	0.002	0 - 0.006	0.1	0.0019	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD= Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA= Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 3

AFTER CLEAN-UP

Job Number 81229

Sample	FIBRES OF ALL LENGTHS: Fibre Concentration: Mean (Fibres/mL)	FIBRES OF ALL LENGTHS: Fibre Concentration: 95% Confidence Interval (Fibres/mL)	FIBRES OF ALL LENGTHS: Estimated Mass Concentration (Nanograms/m³)	FIBRES OF ALL LENGTHS: Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Fibre Concentration: Mean (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Fibre Concentration: 95% Confidence Interval (Fibres/mL)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Estimated Mass Concentration (Nanograms/m³)	FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH: Concentration Equivalent to 1 Fibre Detected (Fibres/mL)	Fibre Type *
SEPTEMBER 15, 1981									
Filter 2647-23 1st Floor (Basement)	0.022	0.005 - 0.039	0.2	0.0022	<0.003	-	-	0.0022	C
	0.002	0 - 0.007	2.3	0.0022	<0.003	-	-	0.0022	AD
	0.004	0 - 0.011	14	0.0022	0.002	0 - 0.007	14	0.0022	SA
Filter 2647-24 2nd Floor	0.025	0 - 0.059	0.3	0.0023	<0.003	-	-	0.0023	C
	0.002	0 - 0.007	31	0.0023	0.002	0 - 0.007	31	0.0023	AD
	0.009	0 - 0.018	66	0.0023	0.005	0 - 0.011	61	0.0023	SA
Filter 2647-25 3rd Floor	0.007	0 - 0.015	0.3	0.0023	<0.003	-	-	0.0023	C
	0.002	0 - 0.007	39	0.0023	0.002	0 - 0.007	39	0.0023	AD
	0.005	0 - 0.011	21	0.0023	0.005	0 - 0.011	21	0.0023	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD = Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA = Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 4

BEFORE START OF PROJECT

Job Number 81166

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	*
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	
JULY 7, 1981									
Filter 2648-1 Basement	0.001	0 - 0.004	0.009	0.0014	<0.002	-	-	0.0014	C
	0.006	0 - 0.013	1.0	0.0014	0.003	0 - 0.007	0.6	0.0014	AD
	0.003	0 - 0.009	0.1	0.0014	0.001	0 - 0.004	0.08	0.0014	SA
Filter 2648-2 First Floor	0.001	0 - 0.005	0.009	0.0015	<0.002	-	-	0.0015	C
	0.001	0 - 0.005	2.0	0.0015	0.001	0 - 0.005	2.0	0.0015	AD
	0.007	0 - 0.015	2.3	0.0015	0.001	0 - 0.005	0.06	0.0015	SA
Filter 2648-3 Second Floor	0.021	0.003 - 0.038	0.7	0.0015	<0.002	-	-	0.0015	C
	0.022	0.007 - 0.038	3.7	0.0015	0.003	0 - 0.007	1.0	0.0015	AD
	0.007	0 - 0.017	0.2	0.0015	<0.002	-	-	0.0015	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD = Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA = Suspected Amphibole (Morphology and EDXA consistent with amphibole)

PROJECT NUMBER 4

AFTER CLEAN-UP

Job Number 81229

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	*
SEPTEMBER 15, 1981									
Filter 2648-26 2nd Floor	0.004	0 - 0.011	0.08	0.0022	<0.003	-	-	0.0022	C
	<0.003	-	-	0.0022	<0.003	-	-	0.0022	AD
	0.004	0 - 0.011	2.6	0.0022	0.002	0 - 0.007	2.5	0.0022	SA
Filter 2648-27 Basement	0.011	0 - 0.029	0.4	0.0022	<0.003	-	-	0.0022	C
	<0.003	-	-	0.0022	<0.003	-	-	0.0022	AD
	<0.003	-	-	0.0022	<0.003	-	-	0.0022	SA
Filter 2648-28 1st Floor	0.008	0 - 0.017	0.05	0.0021	<0.003	-	-	0.0021	C
	<0.003	-	-	0.0021	<0.003	-	-	0.0021	AD
	0.002	0 - 0.007	0.2	0.0021	<0.003	-	-	0.0021	SA

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*AD= Amphibole (SAED)
*C = Chrysotile (Morphology)
*SA= Suspected Amphibole (Morphology and EDXA consistent with amphibole)

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

PROJECT NUMBER 8 (b)

Job Number 82303

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type *
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	
Filter #1 August 10, 1981 Before Removal	0.013	0.001 - 0.025	0.03	0.0032	<0.004	-	-	0.0032	C
	0.006	0 - 0.015	0.1	0.0032	<0.004	-	-	0.0032	A
Filter NUC-OHS-81-38-21 August 19, 1981 During Removal Outside Work Area	0.10	0.052 - 0.15	2.8	0.0039	0.004	0 - 0.012	1.9	0.0039	C
	0.22	0.16 - 0.29	1100	0.0039	0.054	0.025 - 0.083	990	0.0039	A
Filter 41412-NUC-01 December 09, 1981 After Removal	0.052	0.010 - 0.094	1.1	0.0034	<0.004	-	-	0.0034	C
	0.12	0.067 - 0.17	1300	0.0034	0.024	0.005 - 0.043	1200	0.0034	A
Filter 41412-NUC-03 December 09, 1981 After Removal	0.17	0.031 - 0.32	1.9	0.0053	<0.006	-	-	0.0053	C
	0.17	0 - 0.38	21	0.0053	<0.006	-	-	0.0053	A

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (SAED)
*C = Chrysotile (morphology)

SUMMARY OF RESULTS OF ANALYSES BY TRANSMISSION ELECTRON MICROSCOPY

PROJECT NUMBER 9

Job Number 82302

Sample	FIBRES OF ALL LENGTHS				FIBRES GREATER THAN 5.0 MICROMETRES IN LENGTH				Fibre Type
	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	Fibre Concentration		Estimated Mass Concentration	Concentration Equivalent to 1 Fibre Detected	
	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	Mean (Fibres/mL)	95% Confidence Interval (Fibres/mL)	(Nanograms/m^3)	(Fibres/mL)	*
Filter 01 Before Removal Far from work area	1.2 0.074	0.88 - 1.5 0.036 - 0.11	240 1200	0.0117 0.0034	0.064 0.020	0.034 - 0.094 0.005 - 0.035	170 1100	0.0034 0.0034	C A
Filter 04 Before Removal Inside work area	0.51 0.026	0.39 - 0.64 0.008 - 0.043	43 18	0.0043 0.0043	0.009 0.003	0 - 0.019 0 - 0.009	22 8.2	0.0030 0.0030	C A
Filter 03 After Clean-up Inside former work area after barriers removed	1.6 0.25	1.4 - 1.8 0.17 - 0.32	120 800	0.0174 0.0051	0.10 0.046	0.046 - 0.16 0.013 - 0.079	55 690	0.0051 0.0051	C A
Filter 05 After Clean-up Inside former work area before barriers removed	1.4 0.22	1.1 - 1.8 0.066 - 0.37	17 3300	0.0180 0.0180	0.041 0.055	0.005 - 0.077 0.016 - 0.093	6.0 1300	0.0068 0.0068	C A

Where no fibres were detected in the portion of sample examined, the reported maximum concentration is the detection limit equivalent to 1 fibre detected.

*A = Amphibole (SAED)
*C = Chrysotile (morphology)

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